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"Hot Shipping" of Steel Ingots

A MOST interesting experiment in the transportation of hot steel ingots has been conducted by the Dominion Steel and Coal Corporation in Canada, aiming towards reduction of processing time. The ingot was poured at one plant and, as soon as it had solidified, was stripped and placed in a cast iron box insulated with vermiculite. The remaining space was filled with loose vermiculite and the box sealed with a steel lid. The whole box was bolted to the floor of a railway truck.

The experiment entailed moving a 30,000 lb ingot to another plant some 200 miles away. The ingot was at 1700° F at the start of its journey and arrived with a loss of only125 ° F at its destination, where processing was continued with the ingot still at 1575° F. In addition to saving considerable time in cooling and reheating, transportation while hot eliminates the danger of the ingot cracking while cooling off.

Simple Check for Radioactivity

Development of the first simple and inexpensive device to measure the extent of exposure of individuals to atomic radiation capable of mass production to meet both military and possible civil defence needs has been announced in the United States by the Department of the Army. It is a small and light self-developing photographic dosimeter, which may be hung around the neck. A reading can be obtained from the dosimeter one minute after exposure, without recourse to a photographic laboratory or the use of supplementary equipment. The dosimeter's sensitivity can be changed simply by altering the type of photographic emulsion used.

The dosimeter consists of a small metal case containing a flat paper package. The package, or plaque, in turn, contains photographically sensitised film and a pod of developing solution. The film has graduated scales on its outer edges and an unexposed centre part. Exposure to gamma radiation causes the centre strip to turn light—the greater the exposure, the whiter the strip. By comparing the centre strip with the graded scale on the edges, a good measure of the dosage of radiation received by the user can be made. Shielding in the case blocks out alpha and beta radiation, since gamma rays are the ones to be reckoned with in an atomic explosion.

When an individual suspects that he has been exposed to dangerous radiation, he merely pulls a tab from the case. The tab is attached to the film plaque, which is removed. As the plaque passes through a narrow slit in the case, it breaks the pod containing the photographic developing fluids, and spreads the chemicals over the test strip and scale inside the plaque. The user waits approximately one minute, breaks open the plaque, examines the test strip and scale, and learns the extent of his exposure.

Standards for Electrical Measurement

Precise electrical measurements are of fundamental importance to modern science and industry. This is true not only in the communication and power but also in many others where the flexibility and convenience of electrical methods have made them almost indispensable for the measurement of non-electrical quantities. Thus, while in textbooks energy is defined simply in terms of force and length or of mass and velocity, in actual practice the heat energy of fuels and the energy output of prime movers are universally measured to high precision by electrical methods. Likewise, the basic electrical units enter into the determination of nearly all the fundamental atomic constants, as well as into daily measurements of heat, light, colour, strain, acceleration, displacement, and chemical properties.

Effective application of electrical equipment and measurement methods requires uniformity to a high degree of precision in the basic electrical units. Were each manufacturing company to use an even slightly different value for the volt or the ohm, the apparatus made by its sub-contractors would fail to function properly as a part of the final product.

To ensure that the units of measurement used in science and industry are constant through the years, the National Bureau of Standards in the U.S.A. has developed very precise standards of resistance and voltage, the values of which are established by absolute measurements which fix the relation between the electrical units and the fundamental mechanical units of length, mass, and time. From these basic absolute electrical standards, the Bureau has derived other standards for all electrical quantities in use today.

We extend to all readers our best wishes for a Happy Xmas and a Prosperous New Year

FRANCE

Recent Developments in Fire Detectors

By A. SOULIER. (From *Revue Générale de l'Electricité*, Vol. 59, No. 9, September 1950, pp. 367-372, 10 illustrations.)

A survey is given of recent types of fire detectors; of particular interest is a smoke and gas detector which utilizes the phenomenon that a current is set up between two electrodes if gas between them is ionised by a radioactive material

GENERAL

The function of a fire detector is to actuate a fire alarm system with the shortest possible delay after the outbreak of a fire. It was originally thought that a simple contact thermometer would be sufficient for this purpose. However, it was soon found that it was necessary to set the contact for a relatively high temperature if false alarms, due, for instance, to high ambient temperatures in summer or to central heating in winter, were to be avoided. The setting of the contact thermometer for operation at relatively high temperatures, on the other hand, resulted in delayed operation in the event of a fire. It therefore became necessary to develop fire detectors which, instead of operating on a set temperature, would operate on the rate of increase in temperature.

I. AEROTHERMIC DETECTORS

Detectors of this type comprise an air-filled vessel which, except for a pin-point hole, is completely closed. On the occurrence of a slow increase in the ambient temperature, the expanding air is able to escape through the pin-point hole at a rate sufficient to avoid the building up of pressure inside the vessel; if, on the other hand, the temperature increase is rapid, the rate of escape of air is not sufficient to keep the pressure inside the vessel below a set limit. This air pressure is then communicated to the actual alarm system.

A. DETECTOR WITH AIR CYLINDER.

A typical example of this type is shown in Fig. 1. The container R, made of thin copper, is connected to a small cylinder, in which piston P can move with a certain amount of play. The piston actuates an electric switch which, in the case of fire, interrupts the alarm circuit. If the ambient temperature increases slowly, the expanding air can escape through the clearance between the piston and the cylinder; if it increases rapidly, the escape of air in this manner is insufficient and the piston is actuated. In addition, an independent thermostatic (bimetallic) control is provided, which will actuate the switch when a dangerously high temperature is reached, even if the rate of increase in temperature has been slow.

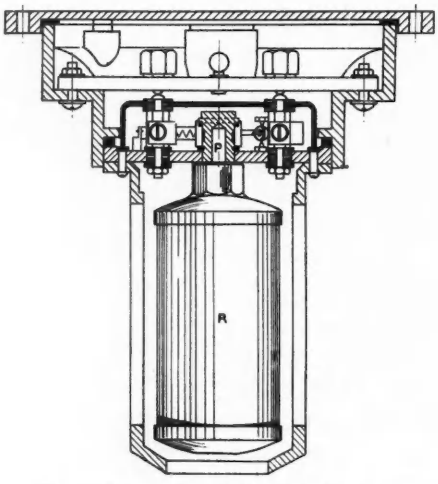

Fig. 1. **Cross-section of air-actuated detector.**

The play between the piston and the cylinder being very small, it is necessary to protect the surfaces against oxidation. To achieve this, the contact surfaces are polished, and are gold-plated by a special process which ensures perfect adhesion of the plating. The contacts of the switch are of a gold alloy on a silver base.

B. TUBULAR DETECTORS.

These operate on the same principle as the detectors with air cylinders, which in this case are replaced by thin-walled copper tubes 3 to 10 mm in diameter and of appropriate length. Detectors of this type are less conspicuous and are, therefore, better suited to meet aesthetic and architectural requirements. Furthermore, the mechanical parts of the detectors (the actuating piston, switch and thermostat) can be installed at a remote distance from the detector tube.

C. DETECTORS WITH BIMETALLIC STRIPS.

These comprise two bimetallic strips, wound in right-hand and left-hand spirals, the one coiling and the other uncoiling on the occurrence of an increase of temperature. This detector can be used for two purposes, namely, to indicate a slow-burning fire as well as rapid, but temporary, increases in temperature, as may occur, for instance, in furnaces and ships' holds.

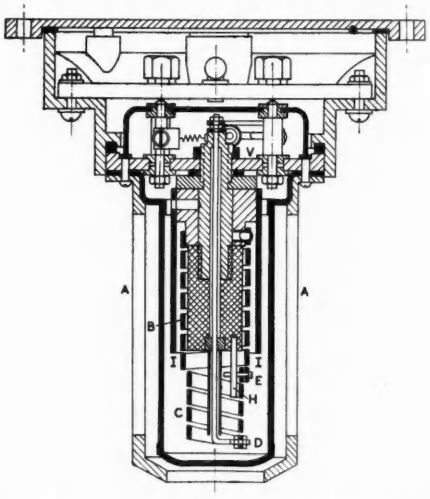

Fig. 2. **Cross-section of detector actuated by bimetallic strips.**

Such detectors consist of a cylindrical cage AA (Fig. 2), containing the two bimetallic spirals, B, C, as already described; these are mounted one in continuation of the other and are joined together. The strips from which they are wound are of different thicknesses,

the spiral nearest the base being thermally shielded by a cylinder of thermal insulating material (I).

On the occurrence of a rapid increase of temperature, the more sensitive lower spiral C will heat up before spiral B, which is both shielded and of greater thermal inertia. Consequently, the terminal point D will be displaced and turn the spindle attached to it, which will operate the electrical switch. If the temperature increases slowly (within a set limit), both the upper and the lower spiral will be able to follow the change simultaneously, and each will compensate the deformation of the other; consequently, point D will remain at rest and the switch will not be operated, although the point where the two spirals are joined together will, of course, be displaced. This movement of the joint is made use of for actuating the switch when the permissible limit of temperature is reached, although the *rate* of increase may have been small. This is accomplished by providing a stop, H, which is set so as to hold the movement of the joint at the position corresponding to the critical temperature. On a further increase of temperature, the compensation through the upper spiral being suppressed, the terminal D of the lower spiral will move and the switch will be operated through the spindle connected to it.

II. DETECTORS USING A WHEATSTONE BRIDGE

This type of detector is based on the change in resistance of a conductor on the occurrence of a change of temperature. Resistances are placed at various points of the premises to be protected and any changes that may occur are registered at a central control point. The well-known Wheatstone Bridge circuit is used for this purpose, the resistances being so connected as to form the four branches of the circuit (Fig. 3). Thus, if the

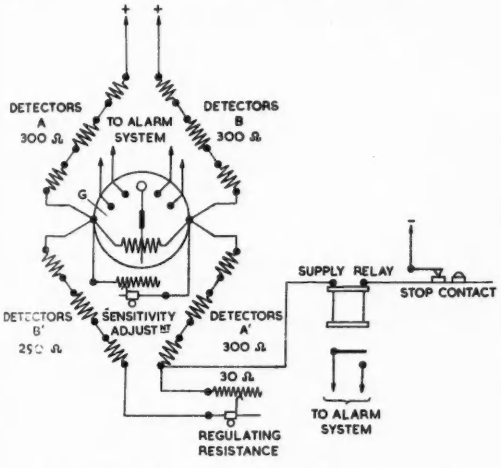

Fig. 3. **Schematic circuit diagram of Wheatstone bridge type detector.**

temperature increases naturally, a simultaneous change of resistance will take place in all the resistance elements connected, and no current will flow through the indicating instrument. If, however, a fire breaks out, there will be a variation in the resistance of those detector elements situated closest to it, to which there will be no corresponding change in the other elements. Consequently, the indicating instrument will be actuated. If this is directional, it will at the same time indicate in which of the two halves of the system the change of temperature has occurred. Each of the branches of the bridge can be made up of a number of resistance elements, making it possible to use one detecting system for a number of rooms. No-voltage relays must, of course, be provided to indicate any failure in the supply of current.

The resistance elements are usually made of thin nickel wire, which has a low thermal inertia and a relatively high thermal coefficient of resistance. They are usually mounted either blank or in perforated protective tubes on or near the ceiling. For reasons of sensitivity, the number of elements that can be connected in series to form one branch of the Bridge circuit is limited to about 10; where a larger number of rooms is to be protected, the elements can be connected in groups, each forming the four branches of a bridge circuit, and a clockwork mechanism can be used to connect these in rotation to a common indicating instrument and battery. In this manner, up to about 800 points can easily be controlled from one central control board. To avoid false alarms, rooms protected by a common bridge circuit must have similar heating arrangements.

III. DETECTION OF GAS AND SMOKE

Frequently, a warning is required, not of a fire that has already broken out, but of conditions likely to lead to the outbreak of a fire. This is particularly important where spontaneous combustion may take place, as in ships' holds and stores, containing rags and similar materials, the developments actually preceding the fire being generally such as to make the spread of the fire, once it has broken out, extremely rapid.

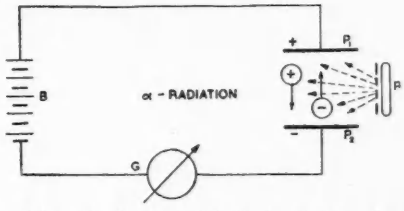

Fig. 4. **Schematic diagram of ionisation type smoke detector.**

Gas detectors developed for this purpose are based on the fact that a current is set up between two electrodes if the gas between them is ionised, which can conveniently be done by α-rays emitted from radio-active materials (Fig. 4).

The intensity of this ionisation current is a function of the voltage applied to the electrodes, the lengths of the gap, the intensity of the irradiation, the nature of the gas between the electrodes, and, in particular, the size of the gas molecules. All conditions being equal, the current is the smaller, the larger the average size of the molecules in the gap. As gases produced in fermentation and low-temperature combustion processes form, in general, groups of molecules larger than the average size of molecules in air, the ionisation current in the circuit shown in Fig. 4 is appreciably reduced as soon as traces of such gases reach the space between the electrodes. This effect is produced by visible as well as invisible

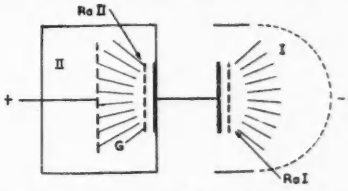

Fig. 5. **Schematic arrangement of ionisation chamber.**

gases, but the presence of dust particles and, to a larger extent, water vapour, has no influence.

The decrease of the current flowing in the ionisation chamber can, in theory, be directly utilised for signalling. It must, however, be remembered that the intensity of the ionisation current is dependent on the intensity of irradiation, and, hence, on the quantity of radium salt used. This being very expensive, only the smallest possible quantity can be used in practice, and other means had to be found to obtain current variations of sufficient magnitude to actuate signalling equipment.

The method adopted in the apparatus described in the following utilises the voltage drop across a resistance connected in series with the ionisation chamber; in this particular case, a second ionisation chamber, operating beyond its saturation point, is being used for this purpose (Fig. 5). Ionisation chamber I consists of a metal grid forming the negative electrode, and a radium salt covered metal plate forming the positive electrode. Ionisation chamber II consists of an almost (but not completely) airtight cylindrical container forming the outer (negative) electrode enclosing a metal grid, which forms the positive electrode. Radium salt is deposited on the inside surface of the cylindrical container. The two chambers are dimensioned in such a way that chamber II operates beyond the point of saturation of its characteristic when chamber I is still well below it. Fig. 6 shows the characteristics of the two chambers. The voltage U is chosen so that the current flowing through the two series-connected chambers remains practically constant when the characteristic of chamber I changes owing to the inflow of combustion gases.

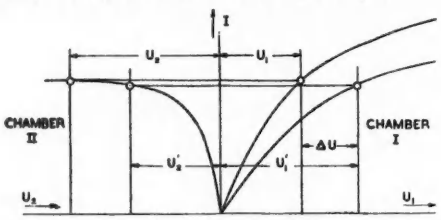

Fig. 6. **Current characteristics of the two ionisation chambers.**

Under normal conditions, i.e., in the absence of smoke, the total applied voltage U is divided by the two chambers into two components, U_1 and U_2. In the presence of smoke, these components change into U_1' and U_2'. The total applied voltage remaining constant, it is

$$U = U_1 + U_2 = U_1' + U_2'$$

and the change of voltage across chambers I and II respectively is

$$\Delta U_I = U_1' - U_1$$
$$\Delta U_{II} = -\Delta U_I$$

Using an operating voltage of 220V, a change of voltage across one or the other of the chambers of up to 60V can be obtained with a sufficient concentration of combustion gases.

The voltage drop across the chamber is applied to a gas discharge relay of high sensitivity (Fig. 7). The actuating voltage between the anode and the cathode is over 250V, so that no discharge is initiated on the application of the operating voltage of 220V. However, between the cathode K and the control electrode S, the striking voltage is about 110V. Thus, if a potential of about 80V is applied between S and K (corresponding to the voltage of equilibrium between the two ionisation chambers) no discharge takes place; if, however, this voltage is increased to about 110V, discharge takes place immediately between A and K. The discharge tube thus operates like an electrostatic relay.

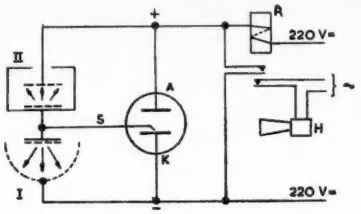

Fig. 7. **General circuit diagram with gas discharge relays.**

Fig. 7 shows the circuit diagram of the complete detector. The control electrode S is connected to the common point of chambers I and II. An increase in the tension across chamber I, resulting from an increase in its apparent resistance, causes a spark to strike between S and K, which, in turn, ignites the main discharge between A and K. The discharge current actuates the relay R, which sets into operation the alarm signal H.

Fig. 8 shows a schematic cross-section of this detector. Ionisation chamber II is arranged inside chamber I. Chamber II is mounted in such a manner that combustion gases can enter it only with difficulty and so that the capacity between the control electrode S and the cathode K is sufficient to store the amount of energy required for the initiation of the ignition spark (approximately 30 μF).

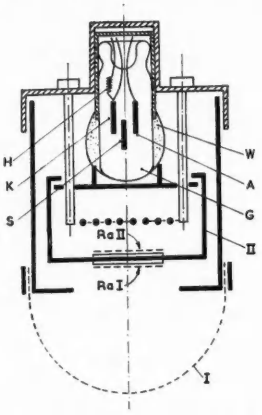

Fig. 8. **Schematic cross-section of ionisation type gas detector.**

For normal operation of the detector, it is essential that the insulation resistance between the common point of the two chambers and the control electrode S should be as high as possible. During operation, this should be higher than 10^{12} ohms. This high degree of insulation is obtained by suspending chamber II directly from the discharge tube. As, however, ordinary glass does not meet these very stringent requirements, the tube is covered with a layer of special wax (W) of exceptionally high resistance, even at a high degree of humidity in the surrounding air. To maintain this resistance in the case of a rapid drop in the ambient temperature during conditions of high atmospheric humidity, which might lead to the formation of dew on the coating, the tube is provided with a heater filament (H). This is permanently connected and has a consumption of only 1 to 1·5 W; it operates below red heat and its purpose is to keep the tube constantly above the ambient temperature.

The radium salt used has a half-life of several hundred years. The whole detector is mounted on an insulated base and protected by a cover with suitable openings at the base.

Measurement of Surface Wear

By H. MEINCKE. (From *Metalloberfläche*, Vol. 4, No. 10, October, 1950, pp. 145-151, 7 illustrations.)

Surface wear is an important consideration in the design of many structural and machine elements. The amount of wear, apart from depending on design factors such as loading, rubbing velocity, and choice of lubricant, depends chiefly on the surface properties of the materials employed. Abrasion can cause an appreciable loss of efficiency and, in severe cases, complete breakdown. For this reason, methods of surface wear testing are of great importance in the development of suitable materials and their surface treatment.

THE purpose of this investigation was to establish standard criteria of abrasion measurement, such as already exist, e.g., in surface hardness testing. Abrasion tests as hitherto employed do not conform to any particular set of conditions and are not comparable with each other. It is suggested, therefore, that the amount of abraded material should be measured for given surface pressures, rubbing velocities, and a fixed time interval, thus yielding reproducible results.

ABRASION TESTING MACHINES

A number of testing machines of different design exist, of which the best known in Germany is probably the "abrasion lathe" of E. H. Schulz. With this machine, a square test piece is pressed with known force against a rotating steel cylinder and the amount of wear is measured for a given time of operation. A modification of this design uses a smaller, Widia-steel abrading cylinder and the results appear to have a reasonably narrow statistical spread. Another design employs a load-carrying arm with a hard-steel surface, bearing on the test piece, over which it is moved in a reciprocating motion. Such a machine was used in the present series of experiments, as it was found to give more consistent results. The total travel of the abrading surface and the pressure were adjustable. The previously weighed test piece is locked underneath the loaded arm, the test started, and after performing the required number of abrading movements, it is automatically stopped by means of a revolution-counter switch.

TYPES OF SURFACE WEAR

Abrasion takes place only if there is no liquid film between the surfaces, and therefore dry friction was employed throughout the experiments. Friction between two solid surfaces takes place in the form of (a) pure sliding, (b) pure rolling, or (c) combined sliding and rolling motions. The experiments were based on pure sliding motion, as this is the most important cause of wear in practice. Three types of wear may be distinguished in this case: (1) Breakaway of grains; (2) fretting corrosion; and (3) plastic deformation. The latter usually appears in the form of burr-formation with subsequent splintering.

EXPERIMENTAL CONDITIONS

The materials tested were red brass, bronze, wrought aluminium alloys, and surface-coated aluminium sheet. They were weighed to the nearest milligram. The abrading head was made of Widia steel to avoid surface roughening which might cause a chipping effect in addition to abrasion. The test pieces were all ground to the same surface finish and the surfaces cleaned with alcohol. Tests were carried out with loads varying from 0·2 to 5 kg/cm², rubbing velocities from 0·56 to 3·0 m/sec, and total travels of 2,000, 4,000 and 10,000 metres. Two different abrading heads of 10 × 10 mm and 10 × 5 mm area were used. No appreciable heating effect was observed under these conditions, and thus no connection between wear and heating could be established. Only when abrasion goes over into scratching does a noticeable temperature rise occur, coupled with a considerable rise in power consumption.

As was to be expected, the smoothness of the rubbing surfaces influences wear to a greater extent than the strength and hardness of the material. A harder abrading head (boron carbide) gave a smaller amount of wear than a softer one (tool steel). To eliminate the influence of surface smoothness on the test results, it is therefore desirable always to start with the same grade of surface finish.

EXPERIMENTAL RESULTS

The results quoted are averages of four series of tests. The maximum deviation from the mean was ± 8·74 per cent. Figs. 1 to 4 give the relations between abrasion and load, rubbing velocity, and duration of test respectively.

(*a*) *Influence of Load.* Fig. 1 shows the relation between abrasion and surface pressure for high loads. A rapid change of gradient is noticeable at about 18·8 kg/cm² pressure, obviously representing a transition to scratching. At 22·7 kg/cm², an abrasion of 900 milligrams was measured, which is well outside the range of the graph. Considerable roughening and groove-formation on the surface as well as a temperature rise were observed. It may be assumed that there exists a critical point of abrasion in this region.

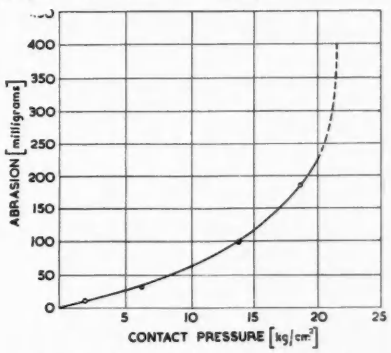

Fig. 1. **Abrasion of a weld-deposit as a function of contact pressure.**
Total travel 8955 metres, rubbing velocity 2·74 m/sec.

It was necessary, therefore, to use load values well below the critical value for all the materials tested, in order to get comparative results. Fig. 2 shows the abrasion-load curves obtained, and it can be seen that they are linear for small loads and go over into parabolic curves as the load is increased. A standard scale of loading is recommended to secure uniformity of test conditions for all materials, starting with 0·5 kg for thin surface layers (e.g., silver plating) to 5 kg for steel. The use of loads smaller than ½ kg is not advisable, as the wear curves for all materials are very close to each other in this region whilst the scatter of test results is large.

(*b*) *Rubbing velocity.* The dependence of abrasion on the rubbing velocity is shown in Fig. 3, and it can be seen that the velocity has practically no influence on wear within the range considered. All curves must, of course, pass through the origin, and therefore velocities below about 0·6 m/sec are not suitable for comparison purposes. The recommended range is 1·0 to 2·5 m/sec.

(*c*) *Duration of test.* The relation between the total

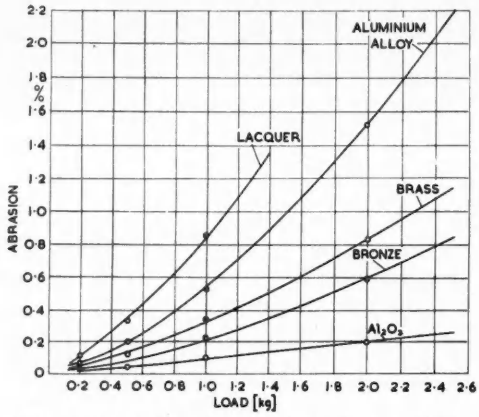

Fig. 2. **Abrasion as a function of the load.** Total travel 1000 m.

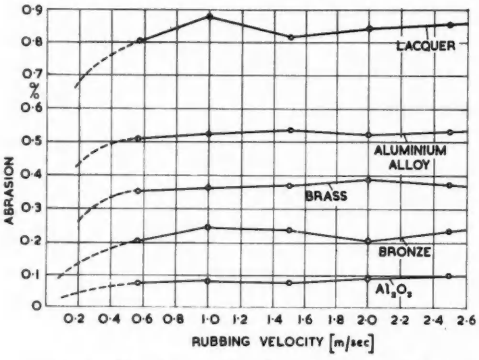

Fig. 3. **Abrasion as a function of rubbing velocity.** Travel 4000 m with a load of 1 kg.

distance covered (i.e., the duration of the test) and percentage of wear is shown in Fig. 4 for a rubbing velocity of 1·5 m/sec. As this relation is practically linear, the duration can be adapted to the physical properties of the material tested, e.g., to the thickness of the surface layer. However, a total travel of at least 2000 metres is recommended.

Surface hardness measurements of very thin layers (e.g., lacquer) are difficult to perform; abrasion measurements, however, are quite feasible and can thus be used to give additional indication of surface quality. The same argument applies to the testing of very brittle surface layers.

Tests on constructional materials such as red brass, bronze, and aluminium alloys showed that, despite the almost identical hardness value of 65 kg/mm², their resistances to wear are quite different. Aluminium alloy especially shows large variations for small changes in composition and heat treatment, and abrasion tests should therefore be indispensable in their development.

INFLUENCE OF METAL STRUCTURE

All the elastic properties of materials are determined by the forces of adhesion between crystals and the cohesive forces within the individual crystals. As the adhesive force is porportional to the crystal surface, it increases with fineness of grain. These considerations apply to wear resistance, as large inhomogeneities in the surface (coarse grain) will cause the crystals to break away more easily. Elastic crystals resist wear better than brittle ones, as they will suffer greater deformation before being torn away, thus absorbing more of the frictional energy.

The amount of wear depends not only on the surface properties, but also on melting point and compressive strength of the material. Actual conditions of abrasion are closely reproduced with the test apparatus. Here too, a hard high melting point metal rubs against a softer one with a lower melting point, eventually forming grooves in the latter. The softer grains are first removed by the friction, leaving the harder ones exposed, bearing against the abrading surface.

According to an older theory, the harder grains, embedded in a plastic carrier, take up the load, while the plastic matter yields so as to distribute the load more evenly over the hard grains. The author's observations support this theory. In the case of an alloy with a hard carrier (copper) with softer interspersed grains (lead), the hard surface carries the load, while the actual sliding motion takes place on a thin film of the softer metal. With hard grains in a soft metal, it often happens that they become welded to the hard steel abrading head, causing scratches in the surface from which they have been removed.

In contrast to the old theory, newer investigations indicate that the harder grains do not in fact affect the abrasion properties to any great extent, but decisively.

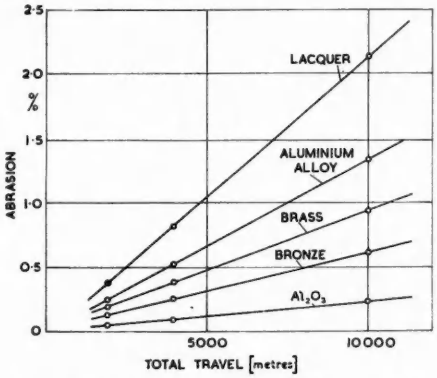

Fig. 4. **Abrasion as a function of frictional travel.** 1·5 m/sec rubbing velocity with a load of 1 kg.

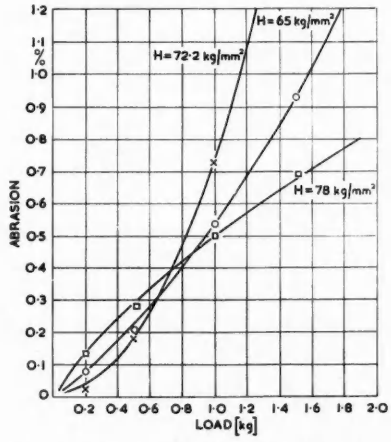

Fig. 5. **Relation between abrasion and load, for aluminium alloys of different Brinell hardness values.**

influence the physical and mechanical properties of alloys.

HARDNESS AND WEAR RESISTANCE

It might be assumed that a greater Brinell hardness implies greater wear resistance. A reference to Fig. 2 shows that this is by no means the case, as, for instance, the aluminium alloy sample with a hardness of 65 kg/mm² has a much smaller wear resistance than red brass with a hardness of 62·4 kg/mm². Results of separate tests on three aluminium alloy samples of different hardness are shown in Fig. 5. No systematic relation between hardness and wear resistance can be detected. This fact may be explained by the difference in the two testing procedures, hardness testing being of a static nature, and abrasion testing of a dynamic nature. However, a relation between scratch hardness and abrasion test should exist, as both are produced by dynamic processes, and they have in fact been found to be directly correlated. Wear resistance of single crystals has also been investigated, and here also it was found to be correlated with scratch hardness and not with Brinell hardness. The substitution of sclerometric for abrasion tests would still be impracticable, however, as the factor of proportionality would have to be established separately for each material.

TEST RECOMMENDATIONS

The experimental results indicate that wear resistances of different materials can, in fact, be compared, if fixed experimental conditions are given. It is essential to start with uniform surface conditions, and a fine-machined surface has been proved satisfactory for this purpose. The direction of rubbing should preferably be the same as that of machining.

The size of the test pieces should be standardised, and the ranges of rubbing velocity (1·0 to 2·5 m/sec), surface pressure (0·5 to 10 kg/cm²) and frictional travel (2000 to 10000 m) as discussed above will satisfy the test requirements of all materials encountered in practice.

The suggested measure of wear resistance under given load and frictional travel is the ratio $\delta = V/S$ (gram/mm²), where V = weight of abraded mass, and S = surface subject to abrasion.

U. S. A.

Reliability in Electronics

D. D. KNOWLES. (From *Westinghouse Engineer*, Vol. 10, No. 6, November 1950, pp. 242-244.)

Much research and effort have gone into making tubes rugged and adaptable to industry. Continuing developments, both in tubes themselves and in their application, will improve these devices toward even greater reliability.

ELECTRONICS, a young, progressive branch of engineering, has achieved its stature quickly. And for the most part it has been a resounding success. The fact remains, however, that electronic apparatus has still not matured —it is not yet as reliable as it should be. This situation will not be corrected unless the importance of reliability is recognized, and then only if all concerned spend the necessary effort and money towards this end. It requires the best efforts of the tube designer and manufacturer to make better tubes, and the equipment designer and manufacturer to make better equipment, and an educational program to teach the user how to maintain and utilize such electronic equipment and tubes in his plant.

The electron tube itself is a common denominator in all electronic apparatus. Undeniably, electron tubes are not as reliable as motors, transformers, resistors, etc. —not because the tube manufacturer wants it that way, but because too little is yet realised about their application (or, for that matter, their basic principles). To gain a better understanding of this situation, let us analyse the various factors that contribute to electron-tube operation, especially those that affect reliability.

CATHODES

Every tube has a cathode of some kind, the duty of which is to emit electrons. In spite of the widespread use of cathodes, the exact detail mechanism of electron emission is still a matter of argument.

Except for pure metal filaments, most cathodes are complicated composite materials, such as oxide coatings, deposited on metal cores ; or they can be some form of metal impregnated with other materials, as, for example, thoriated tungsten. Their operation depends on a fine balance between diffusing a sufficient amount of emissive element to the surface as opposed to evaporating too much of the emissive element. Cathodes are sensitive to contamination by minute impurities, which can come from other elements of the tube, from the glass, or from chemicals that have been used to clean tube parts. These composite cathodes must be run close to their rated temperatures in order to get satisfactory operation. This imposes a hardship on the equipment designer because he may have to supply voltage regulators or take the consequences of impaired operation and life if he omits the necessary voltage control.

VACUUM TIGHTNESS

All electron tubes must be vacuum-tight in order to continue operation. At least they must be essentially vacuum-tight. Any tube manufacturer gets a certain amount of " shrinkage " because some tubes leak sufficiently fast to be caught at inspection and rejected. Undoubtedly a certain number of tubes are shipped that leak so slowly as to defy detection. As a matter of fact, it was recently stated that probably no one has yet made a really vacuum-tight tube. Those tubes that are called " vacuum-tight " simply leak so slowly that they may last for many years without becoming too gassy and give trouble.

GAS CONTENT

Other electronic tubes, such as gas-filled thyratrons, depend upon the maintenance of a specific gas pressure throughout their operating life. In electron tubes two mechanisms occur—namely, the gradual evolution of gas from certain metal parts due to temperature and electron bombardment ; and the gradual absorption, or clean-up, of gas by other surfaces in the tube. In the high-vacuum type of tube it is fortunate that this gas clean-up mechanism exists. Without it, large high-vacuum power tubes might not be practical. Here the satisfactory maintenance of high vacuum depends in part upon the mechanism of gas clean-up by certain electrodes keeping pace with the gas evolution from other electrodes. Fortunately, in this case, there cannot be too much gas clean-up, since the better the vacuum the better the condition. Failure from this cause results only when gas evolution exceeds gas clean-up.

With gas-filled thyratrons, however, this balance is more delicate, and even with the best-known techniques, gas clean-up eventually develops too low a gas pressure for satisfactory operation and the tube ceases to function.

Grid Emission

Many tubes, such as triodes, tetrodes, and thyratrons, have grids that control the current between cathode and anode. For the control characteristics of the tube to remain constant, the primary emission (due to temperature), the secondary emission (due to electron bombardment), and the current collected or intercepted by the grid must all remain constant throughout the life of the tube. Both the primary and secondary emissions are sensitive to minute traces of impurities deposited on the grid metal. Since cathodes invariably vaporise a certain amount of active material, a grid material must be used that remains constant in its characteristics regardless of contaminations.

Mechanical Design

If a connection fails in a tube, it cannot be repaired and the tube has to be scrapped. Making reliable connections is complicated by the necessity, for other reasons, of using and joining widely dissimilar materials which operate at widely differing temperatures. The choice of joining methods is further limited by the necessity of avoiding any flux or other material that will make the tube become gassy, or any material that will evaporate at operating temperatures and contaminate other tube parts or bridge over insulators.

Another common factor in all tube designs is the problem of insulating the various elements of the tube from one another. These insulating sections may be glass, mica, or ceramic. In most cases they form all or a part of the vacuum-tight envelope and also become a part of the mechanical support for the tube elements. Both glass and ceramic materials are brittle, will withstand only a limited thermal shock, and match more or less imperfectly the metals to which they must be sealed. The insulating sections should be long to improve insulation and short to improve mechanical strength. The designer thus has to compromise between these two requirements, depending upon the application. He has to balance insulating reliability against mechanical ruggedness.

Reliability in Electronics

Probably electron tubes depend for their operation on more little-understood factors than any other product in mass production. Tube people believe that they are making good tubes, but also that they will gradually find out how to make them better. In the meantime, immediate steps can be taken to utilise better the present qualities of tubes.

Many field troubles with electronic tubes come under one or more of the following categories : (1) the use of tubes when some other device would be more suitable, (2) failure to select the best tube for the job, (3) failure to operate the tube at or below its ratings, and (4) actual engineering errors in the design of the circuit and inadequate protective devices.

Thus, equipment engineers can do much to improve reliability of electronic devices. The first questions to ask are : " Is a tube needed and, if so, why ? What will be the consequences of a tube failure ? " In the case of radio or television, the answer is easy because tubes are essential. A tube failure in a radio receiver is an inconvenience, but does no real damage. Also, it does not ruin the refrigerator or the oil burner.

On the other hand, the use of a tube where failure can mean actual loss of property or life is an entirely different matter. This does not rule out the use of a tube, but it does call for serious consideration of alternate methods and the selection of the most reliable solution. Many graduations exist between these two extremes. Electronic devices are used in certain railway signalling systems where life and property are at stake. However, the devices are designed so that any conceivable type of tube fault results in a " safe " failure.

Electronic apparatus is used for rectification, spot and seam welding, induction and dielectric heating, and other manufacturing processes where it is in competition with other methods. The consequences of a failure are usually no greater than the interruption of production that occurs during shut-down. In deciding the economics of the various methods, the frequency and duration of shutdown must be considered to decide intelligently whether to use tubes or not. This involves tube life, ease of replacement, and other circuit design and maintenance considerations.

Tubes, of course, eventually fail and in the long run the rate of failure follows the usual probability curve. Most failures occur close to the average life expectancy, but a certain percentage happens before or after that time, and some tubes fail early in life. If the consequences of failures are serious, then tubes should not be used if there is a more reliable way.

The selection of the best tube is important and far from easy. It requires the co-operation of the user, the commercial man who knows the requirements, the equipment designer, who provides the method, and a tube engineer who knows his tubes thoroughly.

Commercial warranties are not an indication of life-expectancy any more than a 90-day guarantee on an automobile. The technical data sheet alone is not enough because, of several tube types possessing approximately the same ratings, one may be designed for 500 hours' average life, another for 5000 or perhaps 10,000 hours. Tube manufacturers are naturally loath to commit themselves on tube-life expectancy without knowing in considerable detail how the tube is to be used, what the circuit conditions are, and what grade of maintenance the equipment will get.

In his attempt to select the best tube for the job, the equipment designer often consults, directly or indirectly, different tube manufacturers—and gets conflicting answers. These conflicting answers may reflect a varying eagerness to sell tubes, an honest difference of opinion as to what will happen under given circumstances, or, as is often the case, a varying appreciation of the rigid requirements of industrial applications as contrasted to a less exacting sphere of use. In this situation the designer has to decide for himself whose judgment to accept and should make careful tests to determine his choice.

Probably the greatest threat to reliability in electronic equipment is the continual pressure from users and equipment designers to increase the ratings " just a little bit." Hardly a week passes that a tube manufacturer does not get a request to raise the rating on a given tube. Very rare indeed is the question : " How much will tube life and reliability be increased if I use the tube below its ratings ? "

The trend is completely contrary to the desire for greater reliability. The telephone system gets long life and maximum reliability by using tubes at low ratings. Until better tubes are made, the same should hold for industrial apparatus.

Often, laboratory tests must be made to determine if tubes are actually being used within ratings. For example, several cases are on record where the designer thought a tube was being used within its voltage ratings because the transformers could not supply more than the peak voltage ratings. However, oscillographic tests showed that transient oscillations superimposed on the normal voltage nearly doubled the actual voltage applied to the tube. Another common occurrence is that two or more tubes do not divide the load properly, so that one tube is underloaded and the other overloaded. This is especially likely to happen with gas-filled tubes, which do not operate well in parallel unless specific means are provided in the circuit for this purpose.

Considerable benefit can be gained by using tubes under their ratings, and by making actual tests to prove that conditions in a circuit are as they appear to be.

Complete tests on a finished model with oscillograms to show transient conditions will also catch many design errors that would otherwise go unnoticed.

Inadequate protective devices are often a costly factor. Tubes do not, as a general rule, have the factor of safety inherent in other components, so the elimination of a good protective device usually results in the tube acting as a fuse and being destroyed or damaged every time a fault occurs anywhere in the circuit.

Another frequent cause of trouble is the failure of the equipment designer to take into account the extent to which characteristics vary from tube to tube and with life.

There are numerous examples of things that have been done wrong or could have been done better. However, four things will help eliminate many of the problems in the future. First, intensive research and development must be conducted, aimed at improving reliability and life of electronic tubes. If both cannot be done, this should take preference over the invention of new and more exciting types of tubes that would probably still have the same "uncertainty factors." Secondly, greater effort must be put forth on the part of the equipment designer to build reliability into the apparatus and thus get the most out of the tubes as they are today. Third, there must be more consideration of reliability, even where it means a higher initial cost. Last of all, an educational effort must be conducted to improve maintenance of electronic equipment.

GERMANY

The Efficiency of Planetary Gear Trains

By R. POPPINGA. (From *Glasers Annalen*, Vol. 74, No. 8, August 1950, pp. 139-145, 12 illustrations.)

A method of calculating the efficiency of planetary gear trains is demonstrated by means of 17 examples from practice. The efficiencies of the various gear trains differ considerably, and vary greatly with the gear ratio. Although the theoretical results cannot replace experimental data, they indicate what efficiencies may be expected under favourable conditions.

Fig. 1 shows diagrammatically 17 reverted (co-axial) planetary trains. Types I to X are the fundamental forms of 3- and 4- gear planetary trains, and types XI to XVII are frequently applied compound trains. Each of these trains has one driving and one driven member, as distinct from differential gear trains, which will not be dealt with here.

EFFICIENCY OF THE BASIC TRAIN

The calculation of the efficiency of a planetary train is based on the efficiency of the corresponding basic train, which can be calculated for each contact by

$$\eta_b = 1 - v = 1 - \left[\xi \mu \epsilon \pi \left(1 - \frac{1}{i} \right) \Big/ 2 z_1 \right] \quad (1)$$

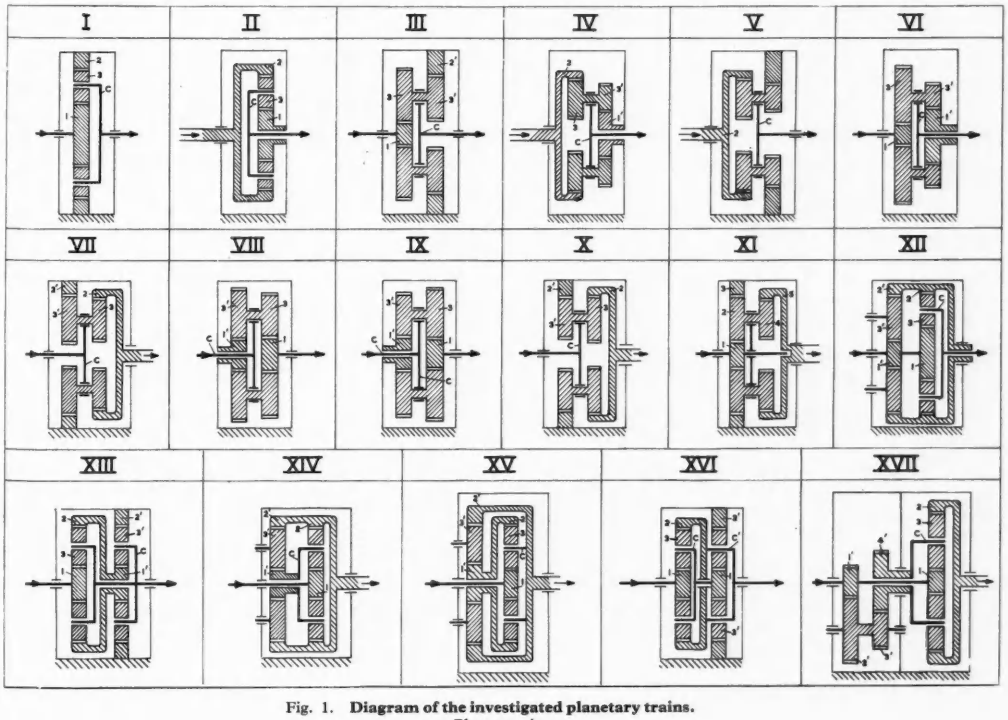

Fig. 1. **Diagram of the investigated planetary trains.**
c = Planet carrier.

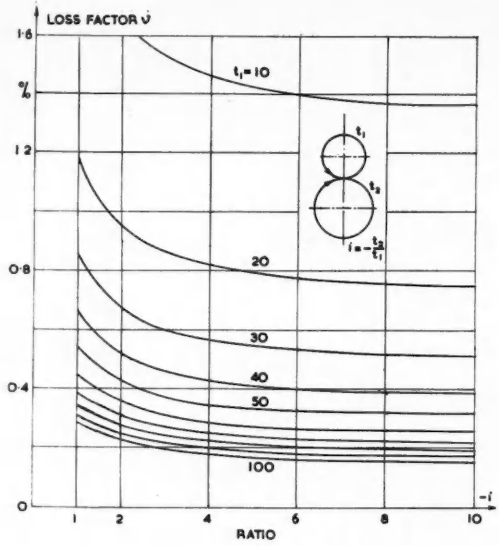

Fig. 2. **Losses of external gears, as a function of ratio and number of teeth of pinion.**

Assumption : Tooth form and pitch-errors are neglected ; involute gears without correction ; pressure angle 20°.

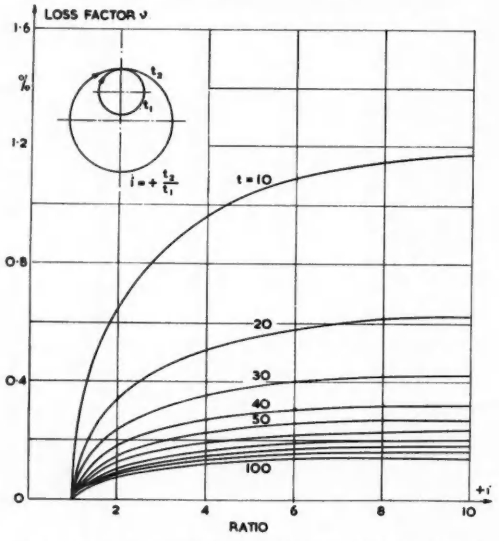

Fig. 3. **Losses of internal gears, as a function of ratio and number of teeth of pinion.**

Assumption : Tooth form- and pitch-errors are neglected ; involute gears without correction ; pressure angle 20° ; internal gears with reduced addenda.

wherein

η_b = efficiency = ratio of output and input power,
ν = power loss = ratio of power loss and input power,
ξ = tooth form and pitch error factor,
μ = coefficient of tooth friction,
ϵ = number of teeth simultaneously in contact,
i = $\pm\, t_2/t_1$ = velocity ratio,
t_1 = number of teeth of (external) pinion,
t_2 = number of teeth of (external or internal) gear,

the — sign pertains to external gears (rotation in opposite direction),

the + sign pertains to internal gears (rotation in the same direction).

Formula (1) does not include bearing losses, which, however, are mostly negligible in comparison with the losses in the gears.

Fig. 2 and 3 show the power losses of external and internal gears respectively, as functions of i and t_1, under the assumption that $\xi = 1$, and $\mu = 0{\cdot}05$. These two diagrams indicate :

1. In both cases, the power loss decreases with increasing number of teeth of the pinion ; this is particularly noticeable between $t_1 = 10$ and 20.
2. For constant t_1, the power loss decreases with increasing ratio i in the case of external gears, while it increases in the case of internal gears.
3. For equal i and t_1, the power loss of external gears exceeds that of internal gears.
4. For values of i slightly larger than 1, the power loss of internal gears is a small fraction of that of external gears.

Modern external gears have an average power loss of 0·5 to 2 per cent for each contact. As pointed out above, the power loss of internal gears is much smaller. The planetary trains under consideration incorporate external and internal gears, and to simplify the calculations, an average power loss of 1 per cent will be assumed for each contact.

THE THREE-GEAR PLANETARY TRAINS I AND II

The basic gear train for the train I of Fig. 1 has a stationary planet carrier and a moving internal gear 2, and it can be obtained if the whole system is rotated with the angular velocity of the planet carrier, but in the opposite direction. Superimposing this additional rotation neither changes the relative velocities of the various members nor the forces, torques, powers, or losses. The loss N_L of the basic train is the difference between the input power N_1 and the output power N_2, or

$$N_L = N_1 - N_2 \qquad .. \qquad .. \qquad (2)$$

if the efficiency η_b of the gears 1 and 3 is assumed to be equal to that of the gears 3 and 2, it follows that $N_2 = (N_1\, \eta_b)\, \eta_b$, or that

$$N_L = N_1\,(1 - \eta_b{}^2) \qquad .. \qquad .. \qquad (3)$$

If ν is substituted for $1 - \eta_b$, and if the small value of ν^2 is neglected, it follows that

$$N_L = 2\,\nu\, N_1 \qquad .. \qquad .. \qquad (4)$$

The circumferential power of gear 1 is

$$N_1 = P_1\, v_{1c} = P_1\, r_{1c}\, \omega_{1c}$$

The subscripts of ω denote the relative angular velocity between the gear 1 and the stationary carrier. The circumferential velocity v_{1c} is the rolling velocity of the gears 1 and 3 (which is identical with that of the gears 2 and 3).

In the case of planetary trains, rolling and circumferential velocities are not identical. In the gear train I, for instance, the circumferential velocity of the gear 1 is the sum of the rolling velocity and the "trailing velocity," added by the rotation of the carrier, or

$$\text{circumf. velocity} = \text{rolling velocity} + \text{trailing velocity}$$
$$r_1\, \omega_{12} \quad = \quad r_1\,(\omega_{12} - \omega_{c2}) \quad + \quad r_1\, \omega_{c2}.$$

The circumferential power can be correspondingly divided into a component N_R due to the rolling action, and a component N_C due to the coupling action of the teeth, so that

$N_1 = N_{R1} + N_{C1}$, wherein $N_{R1} = P_1\, r_1\,(\omega_{12} - \omega_{c2})$.

The subscripts of ω indicate the relative angular

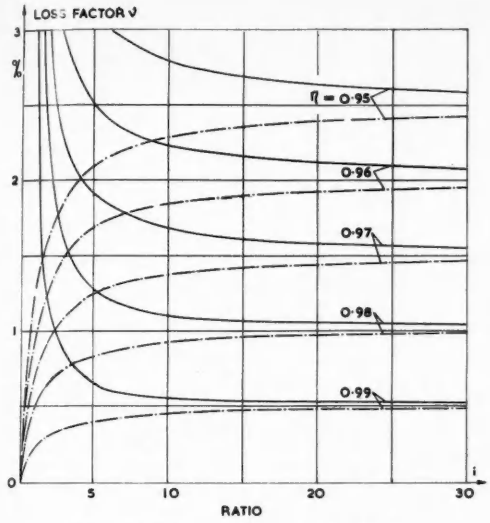

Fig. 4. **Efficiency of the gear trains I to VI.**
Full lines for trains I, II, III, and IV, for rotation in the same direction.
Chain-dotted lines for trains V and VI, for rotation in opposite directions.

velocities of the gear 1 and the carrier c relative to the stationary gear 2. Their difference indicates the angular velocity of the gear 1 relative to the carrier (which has been assumed to be stationary in the basic train), or

$$\omega_{1c} = \omega_{12} - \omega_{c2} \quad .. \quad (5)$$

Rolling velocity and rolling power determine the rating of the gears. As the rolling power of this planetary train is only a fraction of the transmitted power, it can be conjectured that the teeth are less stressed and that the efficiency is higher than in the case of the basic train. The teeth of the planetary train are relieved by the rotating carrier, as the teeth partly act as couplings, without sliding.

If η is the efficiency of the planetary train, the power loss is

$$N_L = N_1 (1 - \eta) \quad .. \quad (6)$$

wherein $N_1 = P_1 r_1 \omega_{12}$.

As the losses of planetary and basic trains are equal, the right hand sides of eqs. (4) and (6) are equal

$$2 \nu P_1 r_1 \omega_{1c} = P_1 r_1 \omega_{12} (1 - \eta)$$

and the efficiency of the trains I and II is

$$\eta = 1 - 2 \nu \frac{\omega_{1c}}{\omega_{12}},$$

which can now be transformed by using eq. (5) and substituting i for

$$\omega_{12}/\omega_{c2} = n_{\text{sun wheel}}/n_{\text{carrier}},$$

$$\eta = 1 - 2 \nu (1 - 1/i) \quad .. \quad (7)$$

If the drive is reversed, i.e., the carrier is driving,

$$\eta = (1 - 2\nu)/(1 - 2\nu/i) \quad .. \quad (8)$$

It is expedient, in these and the following equations to express i always as the absolute value of the ratio of larger and smaller number of revolutions, regardless of the sign which should be assigned according to rotation in the same or the opposite direction.

Equations (7) and (8) yield practically identical values of η, or the direction in which the trains are used does not influence the efficiency. As the full lines in Fig. 4 show, the efficiency, for constant ν, decreases with increasing ratio i.

THE FOUR-GEAR PLANETARY TRAINS III TO X

Equations (7) and (8), as well as the full lines in Fig. 4, are also valid for the trains III and IV. The efficiency of the trains V and VI can be derived from these equations merely by changing the sign of i.

$$\eta = 1 - 2 \nu (1 + 1/i) \quad .. \quad .. \quad (9)$$

$$\eta = (1 - 2\nu)/(1 + 2\nu/i) \quad .. \quad (10)$$

Here again, the direction of the drive practically does not affect the efficiency. In contrast to trains I to IV, the efficiency increases with increasing i, for constant values of ν, as can be seen from the chain-dotted lines in Fig. 4. For the same ν and i, the efficiency of the trains V and VI is somewhat smaller than that of trains for rotation in the same direction, whilst the efficiency of the corresponding basic trains lies between the two.

In principle, the trains IX and X are similar to the trains V and VI. However, in the former case the planet carrier is faster, and in the latter case it is slower than the sun wheel. As it had been proposed to make $i > 1$, the efficiencies for the trains IX and X, for driving sun wheel and carrier respectively, are

$$\eta = 1 - 2 \nu (i - 1) \quad .. \quad .. \quad (11)$$

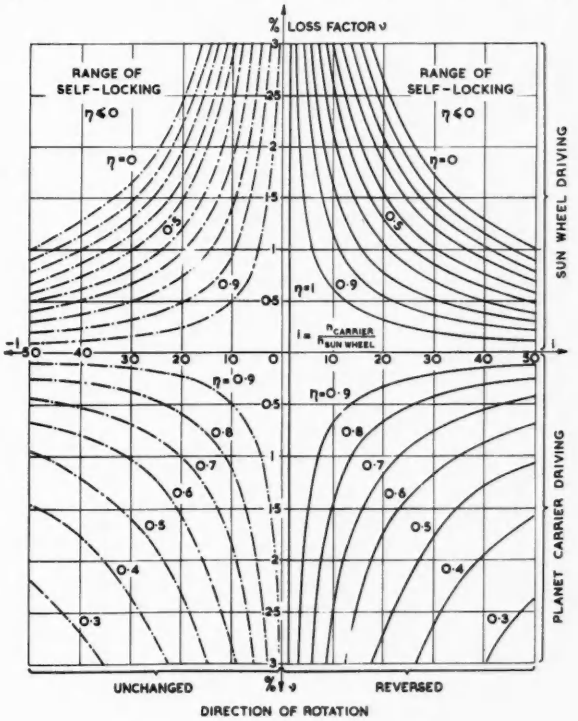

Fig. 5. **Efficiency of the trains VII to X.**
Full lines for trains VII and VIII.
Chain-dotted lines for trains IX and X.

$$\eta = (1 - 2\nu)/(1 - 2\nu i) \quad .. \quad .. \quad (12)$$

where $i = n_{\text{carrier}}/n_{\text{sun wheel}}$.

Equations (11) and (12) yield very small efficiencies in the whole range of i and ν, which, moreover, rapidly decrease with increasing i (ν = constant). The left-hand side of Fig. 5 further shows that the efficiencies are no longer independent of the direction of the drive, the efficiency for a driving carrier being generally larger than for a driving sun wheel. In the latter case, the trains may even become self-locking, and the curve $\eta = 0$ is the boundary for self-locking.

The gear trains VII and VIII are similar, in principle, to the trains III and IV, the difference consisting in the direction in which power is imparted. The efficiency for driving sun wheel and carrier respectively is

$$\eta = (1 - 2i\nu)/(1 - 2\nu) \quad .. \quad (13)$$

$$\eta = 1/[1 + 2\nu(i - 1)] \quad .. \quad .. \quad (14)$$

As the right-hand-side of Fig. 5 shows, the efficiencies of the trains VII and VIII are somewhat larger than of trains IX and X.

COMPOSITE PLANETARY TRAINS

The number of possible combinations of these gear trains is almost unlimited, and only a few examples for the two main groups will be considered here.

The gear trains of the first group are characterized by arranging one simple planetary train in series with another. In some cases this combination is not readily recognisable especially when two gears are combined into one.

The characteristic of the second group is that one of the partial trains is a differential gear which causes a ramification of the power.

1. Combination of trains I and VII (train XI).

The efficiency of a mechanism of this kind is obviously the product of the partial efficiency η_{I} expressed by eq. (7), and the efficiency η_{VII} expressed by eq. (13). By utilising the relation that the total ratio i is equal to the product of the partial ratios i_{I} and i_{VII}, the efficiency is obtained as

$$\eta = \frac{i_{\text{I}}(1 - 2\nu) + 2\nu}{i_{\text{I}}(1 - 2\nu) + 2\nu i} \quad .. \quad .. \quad (15)$$

For increasing ratio, the partial efficiency η_{I} has been found to be slightly decreasing, while η_{VII} is rapidly decreasing. The total efficiency, therefore, becomes larger, the larger the partial ratio i_{I}.

In the case of a large total ratio, it is better to use the gear train III instead of I because it enables a higher partial ratio. With a combination of the trains III and VII, quite good efficiencies may be obtained even for extremely high total ratios. This arrangement can be simplified by replacing the two internal gears by one common gear, and similarly providing only one planet gear meshing with the common internal gear. Such an arrangement has been applied repeatedly in practice, and is shown as train XI in Fig. 1.

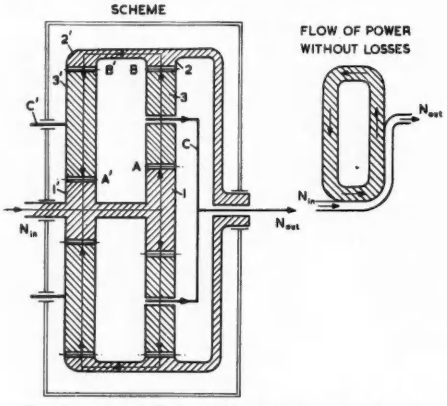

Fig. 6. **Schematic arrangement of gear train XII.**

2. Gear trains XII and XVII.

These compound gear trains have the common feature with the trains XIII to XVI that a member which is stationary in a customary planetary train is driven by the other train. All six trains comprise a train consisting of four rotating members 1, 2, 3, c, and a train consisting of the members 1′, 2′, 3′ (in the case of train XVII, 1′, 2′, 3′, 4′), one of which is fixed. The ratio of this partial train will be called i'.

The gear train XII is shown on a larger scale in Fig. 6. If it is assumed that the combined wheels 1 and 1′ are driving and the carrier c is driven, a part of the power coming from the sun wheel 1 is flowing at point C of wheel 3 into the carrier c ; that part of the power may be called N_{out}. The other part, which may be called N_2, is flowing into wheel 2, and is circulating through the mechanism (there is some analogy with the wattless component of an alternating electric current). The component N_2 flows through the gears 2′ and 3′ into 1′, where it is combined with the input N_{in}. The ramification of the power can thus be expressed by

$$N_1 = N_{\text{out}} + N_2 = N_{\text{in}} + N_{1'} \quad .. \quad (16)$$

Similarly as above, the power loss is the difference between the rolling powers :

$$N_{\text{L}} = N_{\text{in}} - N_{\text{out}} = (N_{\text{R1}} - N_{\text{R2}}) + (N_{\text{R2}'} - N_{\text{R1}'})$$

The power loss is, with $2\nu \simeq 1 - \eta_b^2$,

$$N_{\text{in}} - N_{\text{out}} = 2\nu(N_{\text{R1}} + N_{\text{R2}'}),$$

$$\text{or} \quad N_{\text{out}} = N_{\text{in}} - 2\nu(N_{\text{R1}} + N_{\text{R2}'})$$

Dividing by N_{in} leads, because of $N_{\text{out}}/N_{\text{in}} = \eta$, to

$$\eta = 1 - 2\nu\left(\frac{N_{\text{R1}}}{N_{\text{in}}} + \frac{N_{\text{R2}'}}{N_{\text{in}}}\right) \quad .. \quad (17)$$

To express the first summand in the brackets by ν and i, it may be noted that 1′, 2′, 3′ form a basic train, and that 2 and 2′ are connected. Therefore,

$$N_{1'} = \eta_b^2 N_{2'} = \eta_b^2 N_2.$$

This expression for $N_{1'}$, inserted in eq. (16), leads to

$$N_1 = N_{\text{in}} + \eta_b^2 N_2 \quad .. \quad .. \quad (18)$$

The circumferential powers N_1 and N_2 can be expressed by the rolling powers

$$N_1 = N_{\text{R1}}(1 - 1/i) \quad .. \quad .. \quad (19)$$

$$N_2 = N_{\text{R2}}/(1 + i'/i) = N_{\text{R1}}\,\eta_b^2/(1 + i'/i) \quad .. \quad (20)$$

where $i = n_1/n_c$, and $i' = n_{1'}/n_{2'} = n_1/n_2$.

Combining eqs. (18), (19), and (20), and replacing η_b^4 by $1 - 4\nu$, leads to

$$\frac{N_{\text{R1}}}{N_{\text{in}}} = \frac{(1 + i'/i)(i - 1)}{i + i' - (1 - 4\nu)(i - 1)} \quad .. \quad (21)$$

The rolling power $N_{\text{R2}'}$ in eq. (17) is equal to $N_{2'}$, because there is the case of a basic train, and eqs. (20) and (21) lead to

$$\frac{N_{\text{R2}'}}{N_{\text{in}}} = \frac{(1 - 2\nu)(i - 1)}{i + i' - (1 - 4\nu)(i - 1)} \quad .. \quad (22)$$

By inserting the results of eqs. (21) and (22) in eq. (17), and neglecting ν^2, the final form of the efficiency is reached in

$$\eta = \frac{i' + 1 - 2\nu i'(1 - 1/i)}{i' + 1 + 4\nu(i - 1)} \quad .. \quad .. \quad (23)$$

If the efficiencies of equivalent gear trains XI and XII are evaluated by means of formulae (15) and (23), the gear train XI appears to be superior ; moreover, the train XI is simpler and cheaper than train XII.

The available space does not permit the derivation of the formulae for the efficiency of the gear train XVII, and it may be stated without proof that its efficiency is still lower than that of gear train XII. Here again, the reason is the magnitude of the power component which is circulating through the mechanism. The trains XI, XII, and XVII have the common feature that with comparatively small overall diameters and a small number of gears, they enable very high reductions ; these reductions, however, are obtained at the cost of efficiency. If need be, the efficiency of the train XI can be kept within reasonable limits whilst the other two trains are so uneconomical that their application cannot be recommended.

3. Gear trains XIII-XVI.

These gear trains are very economical, and all have been applied in practice. The efficiency can easily be kept above 90 per cent for the whole range of ratios. However, they do not lend themselves to ratios as high as those of the three gear trains previously investigated.

In the gear trains XIII and XVI, one part of the power is circulating through the mechanism. However, that part is only a small fraction of the transmitted power, whilst it is a multiple of the power transmitted in the case of the trains XII and XVII. The small circulating powers do not unduly affect the efficiency, and the trains are always applicable.

There is no power circulating through the gear trains XIV and XV. The input power is divided into two branches, which are reunited in the driven member. Each of the individual branches transmits only a part of the power, and the gears are less stressed than in trains where the gears are successively transmitting the whole power.

It may be stated, again without proof, that the efficiencies of all four gear trains are practically independent of the partial ratio i' of the gears 1′, 2′, 3′. There is a noticeable influence of small total ratios i. For $i > 10$, the efficiency changes but little, and for $i > 20$, the efficiencies of all four gear trains are almost identical ; the efficiency then only depends on the factor ν.

COMPARISON OF THE VARIOUS GEAR TRAINS

Fig. 7 shows the efficiencies of the discussed trains, for an assumed value of $\nu = 1$ per cent. The trains I to IV, with input and output shafts rotating in the same direction, have the highest efficiencies. The efficiencies are even higher than those of the corresponding basic trains for which η is limited to 0·98, regardless of the ratio. With increasing i, the η-curve for these four trains approaches the straight line $\eta = 0{\cdot}98$ asymptotically.

For the gear trains V and VI, which impart rotation in opposite directions, and the carrier of which rotates at a slower speed than the sun wheel, the efficiency is increasing slightly with increasing i, and the η-curve approaches the straight line $\eta = 0{\cdot}98$ asymptotically from below.

If the numbers of teeth are chosen so as to make the carrier rotate faster than the sun wheel, the efficiencies are very low, as shown by the curves VIII and IX. The curve for the train IX, for rotation in opposite direction, remains below that for the train VIII, for rotation in the same direction.

The efficiencies of the gear trains VII and X are not shown in Fig. 7, because of the uncertainty of the value ν. For a small difference in the number of teeth, it certainly is less than 1 per cent, as can be deduced from eq. (1), but no reliable research data are available. For larger differences in the numbers of teeth, the η-curves of these internal gear trains approximately coincide with

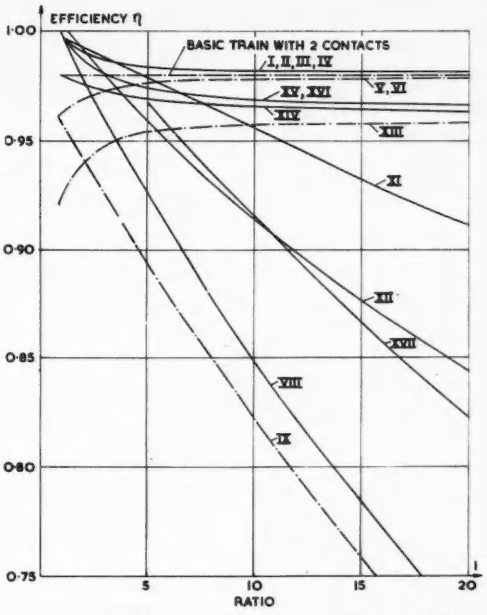

Fig. 7. **Efficiencies of all considered gear trains, as functions of the velocity ratio, for $\nu = 1$ per cent.**
Full lines for rotation in the same direction.
Chain-dotted lines for rotation in the opposite direction.

those for the external gear trains VIII and IX. This is roughly the case if, in the gear trains VII and IX, the diameter of the planet gear is smaller than the radius of the internal gear, so that several planet gears can be accommodated.

The trains VII and X cannot be recommended for ratios less than $i = 30$. For such ratios, the trains I to VI are more favourable because they require less space and have higher efficiencies. These trains, however, cannot be used for high ratios because the overall diameter would become excessive ; for the train IV, for instance, the limit is at about $i = 30$. On the other hand, the trains VII and X, even for very high ratios require only a small outside diameter, and they have been applied for ratios up to $i = 30000$. Such high ratios involve a very small difference between the numbers of teeth of planet gear and internal gear, with correspondingly small friction losses, so that the efficiency can be kept at a reasonable level even for these extremely high ratios.

The external gear trains VIII and IX are, of course, not suitable for such high ratios, but have nevertheless been used up to $i = 1000$. The efficiency of internal gear trains cannot be reached ; for $i = 1000$, the efficiency can hardly be raised far above 10 per cent, and this can only be achieved by best workmanship and under the most favourable lubricating conditions.

The gear train XI is composed of the gear trains I and VII, and is suitable for very high ratios. Its efficiency is far above that of the trains VII and X.

The gear trains XII and XVII have small diameters even for very high ratios. However, they cannot be recommended, because of their low efficiencies.

The high efficiency of the gear trains XIII to XVI is remarkable. The efficiency of these gears is, in their appropriate range, above 95 per cent, and the common asymptote is a straight line $\eta = 0{\cdot}96$, which is the efficiency of a corresponding basic train consisting likewise of 6 gears and 4 contacts.

U.S.A.

New Methods Produce Permanent Moulds

By G. A. ROBINSON. (From *The Iron Age*, Vol. 166, No. 13, September 28, 1950, pp. 82-84, 5 illustrations.)

In order to develop a low-cost and accurate method for the production of castings, a research programme was instigated at the laboratories of Northrop Aircraft, Inc. Preliminary investigations indicated that metal spraying processes might lead to satisfactory results.

THE production of moulds and dies normally requires weeks of chipping, grinding and machining work. Even after the permanent moulds are completed, there is a high casting rejection rate. Shrinkage defects occur owing to unequal cooling shrinkage between the mould and the casting, and porosity is frequently the result of air entrapment in the molten metal or inadequate metal feeding. To avoid these difficulties, sand casting methods are used by most foundries.

In metal spraying processes, the metal is sprayed on a pattern or structure, and the shell thus obtained is removed together with its backing material. The metal powder or wire used is first melted in an oxyacetylene gas flame and the molten particles are then atomised by a compressed-air blast which projects them on the pattern surface. With both ferrous and non-ferrous castings, it was found that favourable results could be obtained by using moulds of high melting point alloys with thermal expansion coefficients similar to those of the casting metals. The moulds are preheated before spraying. Provided the melting and pouring temperatures are accurately maintained, the possibility of shrinkage cracking or porosity defects is considerably reduced. The construction period is extremely short; for instance, a permanent mould for a small pattern with a surface area up to 1·5 sq ft may be made by one man in two days.

Sprayed metal moulds can now be constructed to withstand temperatures up to 2900° F. The backing metal is easily machined, although the moulds and dies may be constructed of metal with a wearing surface of approximately 57 Rockwell-C.

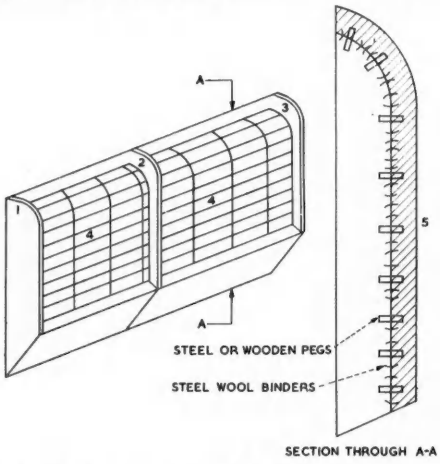

Fig. 1. **Construction of a spray metal pattern of simple shape.**

The method for constructing a simple spray-metal pattern is shown in Fig. 1. A frame is constructed with steel templates (1), (2) and (3). Plaster (4) is added between the templates to within ¼ in. of the upper surface and steel wool particles (5), used as a binder, are distributed in the surface of the plaster, which is then allowed to set. The plaster surface is then coated with a heat-resistant waterproof coating and the metal powder bonding mixture is faired in to produce the required pattern contour.

For complicated shapes, the method may be reversed: The bonding mixture is spread in the bottom of a plaster guide pattern coated with steel wool, and allowed to dry before coating with waterproofing and providing it with a plaster backing. The guide pattern is removed after the plaster backing is dry, and leaves the final pattern, as shown in Fig. 2.

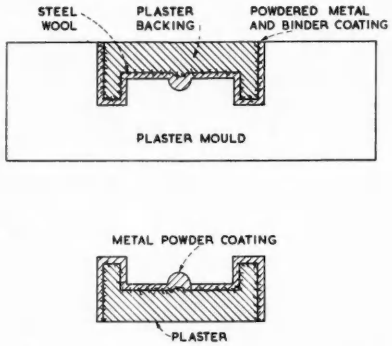

Fig. 2. **Construction of a sprayed-metal mould of more complicated shape. Lower drawing shows pattern removed from mould, ready for spraying.**

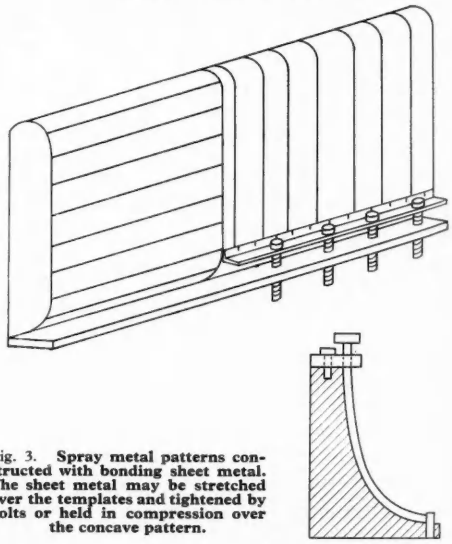

Fig. 3. **Spray metal patterns constructed with bonding sheet metal. The sheet metal may be stretched over the templates and tightened by bolts or held in compression over the concave pattern.**

The bonding coating must be sufficiently strong to resist the air blast from the spray gun and the temperature stresses developed by the sprayed metal. For simple patterns, the bonding coating may be a metal powder mixed with a bonding agent, or it may be sheet metal as shown in Fig. 3. Different bonding mixtures

are employed for the various metals sprayed, the requirement being to have a metal which will soften slightly and bond to the sprayed coating when the sprayed metal hits its surface. To prevent curling of the sprayed metal at the edges, special edge bonding is required. In some cases an edge ring of bonding metal, equal in thickness to that of the mould required, is fastened around the outer edge of the pattern. Seams between bonding metal sheets and other surface imperfections are filled in with bonding metal powder and binding, and the gates and risers required for pouring castings into the finished mould are made of bonding material.

When covering the first layer of the mould, the metal must be atomised to a fine texture, with the spray gun held at about 6 in. from the pattern and moved at a rate of about 5 ips over the surface. Further layers may be sprayed on at a faster rate, until the normal mould thickness of about $\frac{1}{4}$ in. is obtained. To prevent overheating, the gun should not be held in one position for more than 2 sec. Incipient cracks should be coated with bonding mixture and metal spraying continued. For spraying the subsequent layers, the gun is held at about 12 in. from the pattern to avoid overheating, and then brought nearer again to 6 or 8 in. when the coating starts to build up.

Reinforcement may be added and spray-bonded to the coating, after the sprayed coating has been built up to a thickness of about $\frac{1}{8}$ in. As shown in Fig. 4, this may be accomplished by adding angles of bonding material or screens or wire. The blocks may be of coated wood or bonding metal.

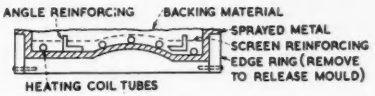

Fig. 4. **Reinforcing and backing of the sprayed metal.**

Joints between the form blocks and the base coating are filled in with metal bonding paints before spraying, and high-temperature-resisting plasters or lower melting metals may be used for additional strength as backing materials. Attaching angles and heating tubes may also be embedded in the backing where necessary.

Shrinkage cracking can be prevented and porosity decreased by using, for instance, high-chromium alloy-steel wire sprayed into the mould and preheated in castings of aluminium. The mould is preheated to 1030° F and the molten aluminium is heated to about 1500° F to remove the entrapped air and then cooled down to 1350° F before pouring. Bright clean castings can be obtained by casting the aluminium in an inert-gas atmosphere.

GERMANY

New Methods for Manufacturing Boiler Fittings by Forging, Welding and Machining

By K. KREKELER. (From *Zeitschrift des V.D.I.*, Vol. 92, No. 30, October 21, 1950, pp. 833-836, 21 illustrations.)

Boiler fittings and pipe connections made from forgings have a high structural strength and afford better possibilities for machining inside the casing, particularly with valves and fittings exceeding 3 in. nominal diameter. With the exception of certain standard components, such as bolts and spindles, most boiler fittings can be built up entirely from forgings. The parts can be manufactured at low cost by using suitably designed forgings which are butt-welded together, with all seams filled-in in one run by means of automatic welding equipment.

THE casings of boiler fittings are generally made of cast iron or cast steel. In some cases, rust- and acid-proof materials are employed; non-terrous metals are also used. Castings may, however, have defects such as blow holes, porosities, etc., which are not apparent at the surface of the material. Moreover, the surfaces inside the casting may not be easily accessible for subsequent machining.

The new manufacturing process described in the following avoids these disadvantages by using forgings exclusively for manufacture. The material recommended for this purpose is C.22 steel with 0·2 per cent carbon and 0·4 per cent manganese, which has a strength of 55 kg/mm² (34·92 tsi). Owing to its favourable carbon content, this steel can be subjected to high forging temperatures so as to obtain a good flow of the material in the die. It also combines good machining properties with adequate strength, and has a structural uniformity which cannot be obtained with castings. The welded component is subjected to a subsequent heat treatment to obtain a favourable grain structure.

DESIGNS OF THE DIES USED FOR FORGINGS

The dies should be designed so that the finished forging will have the correct dimensions required for adequate strength, apart from the surfaces to be machined. Generally, the casings of boiler fittings cannot be forged in one piece. The casing should, therefore, be subdivided into sections which can be formed with a die. In many cases, it will be sufficient to divide the casing into two symmetrical half-sections, so that only a small number of dies will be required. Machining operations can be made at a later stage according to requirements, and the sections are then welded together either manually or automatically.

In designing the die, care should be taken to give the forging as far as possible a symmetrical shape, in order to avoid a one-sided forging tendency, and also to obtain a uniform distribution of the material. Overlap and distortion of the forging in the die are then also avoided. The production process is planned to obtain maximum economy, accuracy and structural strength.

MANUFACTURE OF A FORGED SLIDE VALVE CHEST

The advantages of the forging process will become evident by considering the application of the process to a slide valve chest.

The slide valve chest consists of a central portion, into which the valve disc is fitted, and two flanged portions situated opposite each other. Therefore, the chest will first be split into three parts, viz., the two branches with connecting flanges and the chest proper. Furthermore, as the central portion of the chest is nearly always symmetrical, it will be convenient to cut it in two in the longitudinal direction, so as to have two identical shells.

Owing to the flanged connection, these shells are not

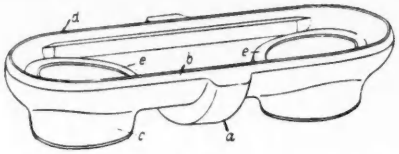

Fig. 1. **Double-shell forging for a slide valve chest.**
a = double flange thickness and saw cut ;
b = chamfer obtained by die for longitudinal welding seam ;
c = shell branch sections ; d = shell supporting surface ;
e = valve seat.

fully symmetrical. This is remedied by making the forging as shown in Fig. 1, with the two half-shells of the central portion of the chest arranged end-to-end and forged simultaneously. The two halves are separated subsequently by a saw-cut.

After forging, the supporting surface of each shell is ground flat to obtain a plane of reference for the machining operations to be performed at a later stage. The shell openings are then machined to the nominal width and are provided with spacers and other elements required for the welding of the flanged members.

The first welding operation is for reinforcing the valve seat with high-alloy chrome-nickel steel or stellite. The surfaces are then turned on the lathe and ground. This process shows the advantage of using forged sections. As all the surfaces of the open shells are easily accessible, uniform welds can be obtained and inspected. In addition, the hard weld deposit can be machined without difficulty. Owing to the hard valve seat obtained by this method, the forged slide valve will have a high wear resistance, and will be extremely reliable in operation.

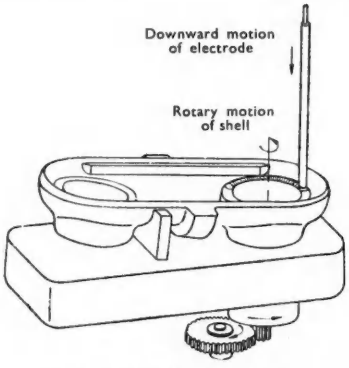

Fig. 2. **Reinforcing the valve seat.**

Details of the welding sequence are as follows :— For reinforcing the valve seat, the double shell is arranged so that it will rest on the two branch sections on the table of an automatic welding machine. The table can rotate about the branch axis, as shown in Fig. 2. The downward motion of the coated electrode, which is usually 4 mm thick, depends on the intensity of the welding current, the table feed, and the rate of deposition.

In the second welding operation, the two double-shell sections of the slide valve are welded together. For this purpose, the shells with the branches are placed in a jig on an automatic welding machine, which performs a reversible longitudinal motion, as shown in Fig. 3 (symmetrical welding). The welding should be arranged to begin and end at the centre of the collar, since the length of an electrode is usually just sufficient for one seam from centre to centre on opposite sides.

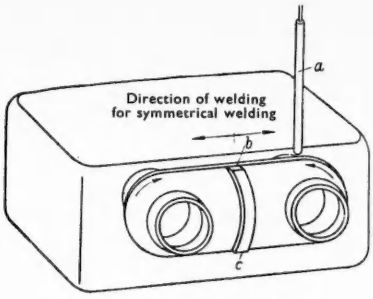

Fig. 3. **Welding together of the double-shell sections of the slide valve chest.**
a = welding electrode, b = beginning of weld, c = end of weld.

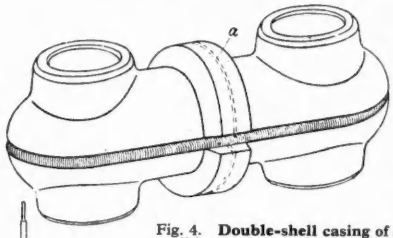

Fig. 4. **Double-shell casing of a slide valve welded together.**
a = line for saw-cut.

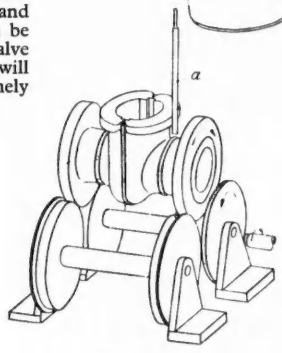

Fig. 5. **Welding of the flange parts on to the slide valve chest.**
a = welding electrode.

Generally, the weld consists of three layers, deposited one over the other. The root seam is welded with an electrode of 4 mm diameter, the intermediate run with a 5 mm electrode, and the sealing run with a 6 mm electrode. After the two double-shell sections have thus been welded together, the chest is cut in two by a saw-cut through the collar along the line marked " a " in Fig. 4.

The slide valve chest is completed by welding-on the two flanges on either side. This welding process is also performed with a mechanical device (see Fig. 5),

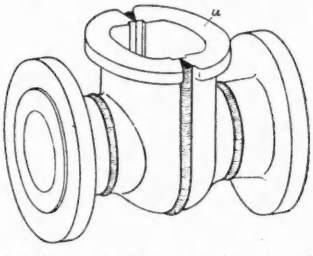

Fig. 6. **Slide valve chest with flanges welded on.**
a = surface obtained by saw-cut.

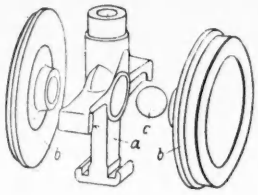

Fig. 7. **Sliding disc arrangement of a slide valve.**
a = disc holder;
b = sliding discs;
c = ball.

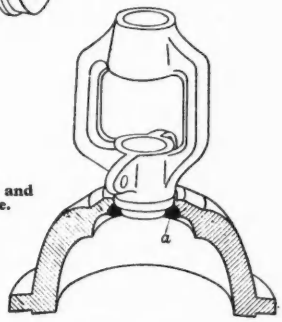

Fig. 8. **Upper cover and yoke of a slide valve.**
a = welding seam.

which rotates continuously and carries the chest with the two flange sections attached and rotating under the electrode. A three-layer weld is again used, with electrodes of 4, 5 and 6 mm diameter. After this, the finished chest (see Fig. 6) only requires machining at the flanges.

The sealing devices, shown in Fig. 7, consist of a disc holder *a*, two sliding discs *b*, and a ball *c*. The disc holder gives adequate support to the sliding discs and allows a rapid stripping and assembly of the various components. The discs are made of heat-resistant steel, which is nitrided after machining. The sealing surfaces are then lapped to obtain a perfect seal when the ball presses with a uniform pressure against its bearing surfaces in the sliding member. The disc holder, the sliding discs, and the ball are all drop forgings. The handwheel is of forged steel and has a reduced cross-section with small overall dimensions. The design is sturdy and particularly suitable for rough handling. The upper portion with the yoke is made of two separate forgings (see Fig. 8) in order to produce the complicated shape required. A fully-welded and assembled slide valve is shown in Fig. 9.

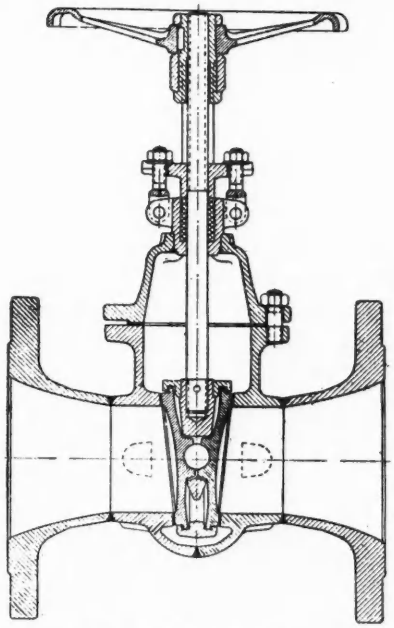

Fig. 9. **Completely welded and assembled slide valve. Nominal diameter 100 mm (4 in.). Nominal pressure 25 atmospheres (367·5 psi).**

MANUFACTURE OF A STOP VALVE CHEST

The stop valve chest can be fabricated from forged components in the same way as the slide valve chest. The valve chest is welded, cut, and put together in the manner previously described. However, in this case, it is hardly possible to employ an automatic machine to weld the double shells together, because of the bends in the welding seams. It is more convenient, therefore, to separate the double shells by means of a saw-cut immediately after the machining operation and to connect the shell portions by means of butt welding. The welding process itself lasts only a few minutes. The valve collar attachment is reproduced in Fig. 10, and the yoke-shaped covers shown in Figs. 11 and 12 can also be forged in spite of their complicated shapes.

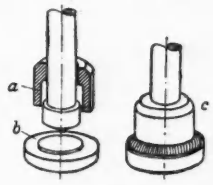

Fig. 10. **Valve cone attachment of a forged valve.**
a = conical collar; b = cone plate of stainless steel; c = welded valve collar assembly.

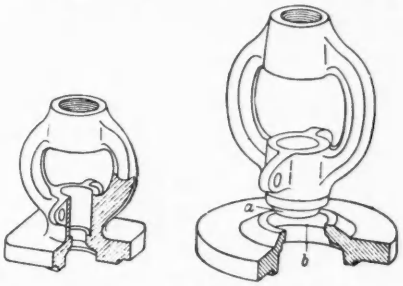

Fig. 11 (left). Design for valves with nominal diameters up to 50 mm (2 in.).

Fig. 12 (right). Design for valves with nominal diameters exceeding 50 mm (2 in.).

Figs. 11 and 12. **Yoke-support and cover of a forged valve.**

A fully-welded valve is shown in Fig. 13. Non-return valves, and valves and cocks for mining equipment can also be manufactured in a similar manner. The equipment for the mining industry must fulfil particularly high requirements as regards the design of the components and the quality of the materials used, in view of the rough handling to which they are subjected in underground work and the corrosive quality of the water available. For such work, all auxiliaries are made as compact as possible and the following design modifications are required :—(1) All spindles are fully enclosed in the casings to prevent possible damage due to falling stones or other causes; (2) the forged handwheels are designed as cowlings over the main

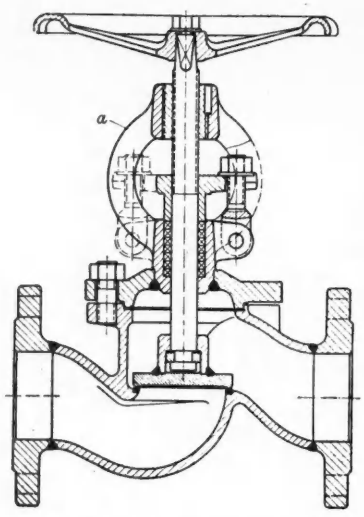

Fig. 13. **Stop valve completely assembled and welded together.**

casing; (3) the valve packing glands are provided with locking nuts instead of bolts, which can be tightened by hand without a spanner; (4) the yoke-shaped sections are replaced by compact heads with spindles and internal threads.

POSSIBILITIES OF THE NEW MANUFACTURING PROCESS

By applying the " Ellira " welding process* in place of the conventional arc welding method with short electrodes and making full use of the double-shell system described in the foregoing sections, boiler fittings can be produced at low cost and with high mechanical properties. The seams are welded in a single operation without air entrapment and the initial and end craters which are inevitable with the usual short-length electrodes are avoided. The seams are not visible in X-ray photographs since there are no slag deposits as in multiple-layer welds. The butt welding of flanged sections to the main casing is performed with automatic equipment. The welded components are extremely sturdy and have been giving fully satisfactory operation at pressures up to 150 atmospheres (2205 psi) and temperatures up to 550° C (1022° F).

*See *The Engineers' Digest*, Vol. 8, No. 10, October 1947, pp. 343-346.

A New Protective Relay

By W. ZANDRA. (From *Maschinenmarkt und Elektrowirtschaft, Austria*, Vol. 5, No. 14/15, August 31, 1950, pp. 343-347, 7 illustrations.)

THE relay is designed for handling currents up to 30A and voltages up to 500 V. It employs air-break switching and a rotary interrupting motion, the former because it is more suitable for the output range than an oil-filled switch, and the latter because it is found to give a more hum-free and reliable service than a linear motion. A life of several million switchings at the rate of 30 switchings per hour is claimed.

The relay, which consists of four pairs of contacts (a section of one is shown in Fig. 1), is held in the closed position by an electromagnet placed between two contacts on either side. The symmetrical arrangement neutralises the torsional load due to the contact pressures, and also helps to eliminate a.c. hum. The relay can be used with or without an additional motor-protection device and, with small modifications, as a d.c. relay. The operation can be understood by reference to Fig. 1. The current enters at *f*, passes through the bimetal junction *l* and the heating coil *m* to the terminal *n*. If motor protection is not required, a shorting clamp connects *f* to *n*. If a 20 to 30 per cent excess current flows, the bimetal junction, by bending, actuates the shaft *q* through the adjustable eccentric *o*. The end of the shaft *q* is, in turn, provided with a switch which breaks the magnet circuit, thus separating the main contacts. The current then passes from *n* through a flexible conductor *r* into the contact arm *u*. The contact pressure is provided by the spring *w*. In the a.c. relay, the current then flows directly through *v*, *v'* to the upper terminal *e*. In the d.c. variant, blow-out magnets are interposed between *v'* and *e*, concentrating the blast field over the contact area by means of suitably shaped pole-pieces.

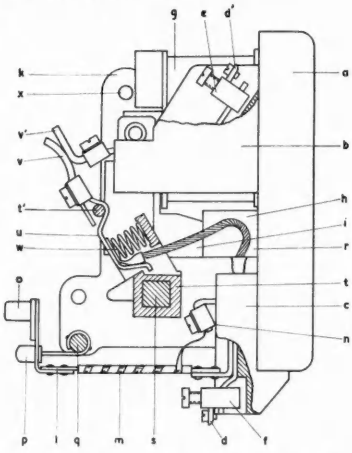

Fig. 1. **Schematic side-elevation of relay.**
a, base plate; *b*, upper terminal holder; *c*, lower terminal holder; *d*, *d'*, auxiliary terminals; *e* and *f*, upper and lower terminals; *g*, magnet coil; *h*, magnet core; *i*, anchor; *k*, left side-plate; *l*, bimetal strip; *m*, heating coil; *n*, heating coil terminal; *o*, eccentric for setting; *p*, lug; *q*, relay switch spindle; *r*, connecting cable; *s*, main contact shaft; *t*, Bakelite contact arm; *t'*, pivot on part *t*; *u*, contact lever; *v*, *v'*, contact surfaces; *w*, contact spring; *x*, hole for blow-out coil mounting.

The magnet system ensures a hum-free pole contact. It operates against a powerful spring, and includes an airgap so dimensioned that a drop of 40 per cent in the energising current is sufficient to cause separation. A d.c. control of the magnet can be provided for by small alterations. The static power consumption of the magnet is 10 W for a.c. and 2·5-5 W for d.c. operation.

The contact surfaces are of the usual design and are easily replaceable. The contact pressure is about 700 grams. The terminals are of an original design and dimensioned to cope with wire cross-sections from 0·75 to 16 mm².

The additional motor protection relay provides safety against overloads and single-phase running, though not against short-circuiting. To cover the range 0·25 to 25 A, a series of nine bimetal strips are provided, each covering a current range of about 1 to 1·6. After each operation, the relay is locked in the open position and must be re-set by hand. The position of the switches is indicated by colours through a small window.

Two or more relays can be combined in a simple manner to give various protective combinations.

Measurement of Atmospheric Overloads in Power Networks

By M. BÖCKMAN. (From *Teknisk Tidskrift*, Vol. 80, No. 14, April 8, 1950, pp. 309-320, 13 illustrations.)

A new type of automatic measuring equipment for atmospheric overloads in networks is described; it can be produced at a reasonable cost and is easy to set up at any station.

THE engineer dealing with practical installation work is not primarily interested in the magnitude of a lightning discharge. What is of importance to him is a knowledge of the effects of lightning on the power network and sufficient statistical data on overload effects in high tension networks to enable him to design suitable protective equipment which, with a minimum of expense, will reduce the risk of damage to reasonable proportions.

With this aim in view, in co-operation with the Lightning Committee of I.V.A., the Asea Laboratories have developed a new type of automatically operating measuring equipment which can be produced at a reasonable cost and which is easy to set up at any station where measurements are to be taken. The main unit in this equipment is a cathode-ray oscillograph. As it was not practicable to use a tube with a very high accelerating voltage and a time sweep capable of giving oscillograms of extremely steep current pulses, the oscillograph unit was made to operate in conjunction with a pulse-steepness indicator and a magnetic device measuring the peak amplitude and duration of the pulse. The indicator is installed in the lightning protection system and gives well-defined voltage levels.

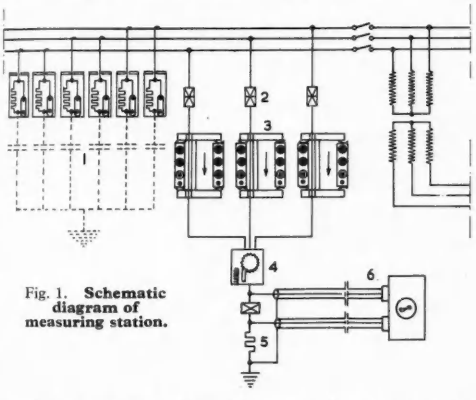

Fig. 1. **Schematic diagram of measuring station.**

A complete measuring station comprises the elements shown in the diagram of Fig. 1. These include the lightning conductors (2), the magnetic pulse-duration indicator (3), the pulse counter (4), the oscillograph (6) with its shunt resistor (5) and, outside on the transmission lines, the pulse-steepness indicators (1). The oscillograph is permanently fitted with a camera and a film case with 21 reels of film. The oscillograph tube is a Du Mont tube, type 5-LP, with a total accelerating voltage of 4 kV, giving a relatively high writing speed. The unit is permanently coupled to the network and the camera is open with the film already in the exposure position, but there is no light signal on the screen until it is released by the voltage pulse. A block diagram of the oscillograph circuit is shown in Fig. 2. A voltage pulse coming from the shunt resistor is applied directly on the measuring plates and also acts on the triggering unit (3) via the phase converter (1), thus starting the time sweep (2). At the end of the time sweep discharge, the triggering stage (4) gives a mechanical impulse to the camera so that a new frame of the film is brought into the exposure position, and the oscillograph is then ready to operate again.

Time sweep : To increase the time during which the camera can remain open without appreciable blackening

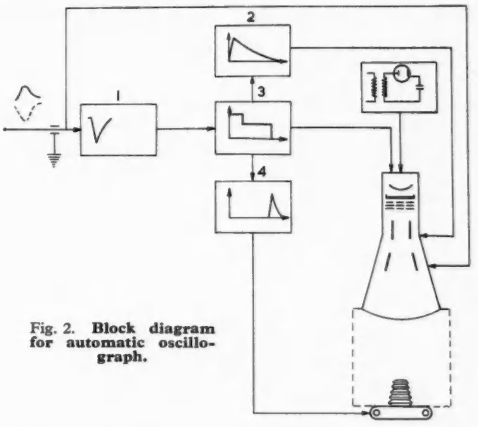

Fig. 2. **Block diagram for automatic oscillograph.**

of the film, a fairly high initial voltage is applied to the time plates, so that the light spot is just off the screen. When a triggering impulse arrives from the lightning conductors, the cathode ray first sweeps across the screen at a fairly high velocity (sweep time approximately 500 microseconds) to record details of the overload voltage front. The spot then goes back to its initial position, but this return trace occurs at two different speeds. The first part of the return stroke is at a high mean speed (sweep time of 5000 μs) in order to obtain the total duration of long-period overload pulses, whereas the last part is at a low speed (sweep time of approximately 1 sec.) for recording multiple lightning pulses or secondary pulses in the lightning conductors. The relatively complicated sweep voltage curve is obtained by means of the fairly simple thyratron circuit shown in Fig. 3.

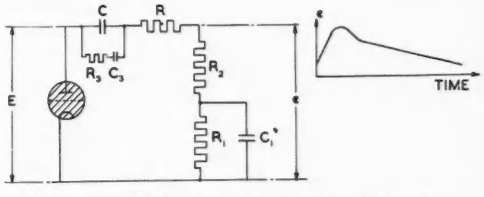

Fig. 3. **Special time-sweep circuit for oscillograph.**

Measuring circuit : In order to be able to measure current discharges over a very wide range, varying from 50 to 20,000 amperes, a logarithmic shunt circuit is used (see Fig. 4). In the earth wire of the lightning conductors is a powerful ohmic resistor of 0·2-0·5 ohm. The voltages across this shunt are transmitted to the oscillograph through measuring cables and a terminal impedance ensuring nearly reflexion-free connection between cables. The impedance includes a voltage-dependent resistance and an ohmic resistor. The oscillograph recordings are measured using a logarithmic scale.

Magnetic pulse time measuring unit : The equipment used also includes a magnetic device for measuring peak amplitudes and pulse duration (see Fig. 5). This device is mainly used to check the results obtained with

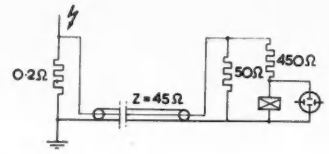

Fig. 4. **Logarithmic shunt with wide measuring range.**

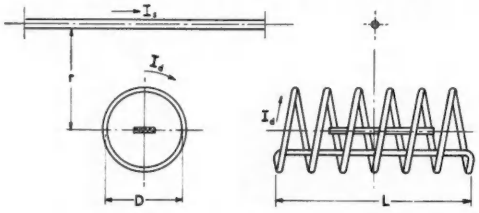

Fig. 5. **Principle of magnetic pulse-duration indicator.**

the oscillograph. A small magnetic bar at a distance r from the current-carrying conductors is situated in the direction of the magnetic flux and placed inside a short-circuited damping coil. Sudden current variations in the current-carrying conductors induce currents in this coil which act against he flux variations, so that the induced currents are damped down. The damping time depends on the coil time-constant. To compare the remanence effect of a bar without a damping coil with that of a similar bar surrounded by a short-circuit coil having a given time constant, use can be made of a pulse lasting long enough for the short-circuit currents in the coil to be damped out and, thus, a measurement of the duration of the current can be obtained. In practice, the magnetic device is designed as shown in Fig. 6. It consists of a bakelite cylinder containing four measuring bars. One of these bars is without a damping coil and the other three have damping coils with different half-value time-constants T_d ranging from 1 to 100 μs. Two magnetic devices of this type are placed at distances of 15 and 150 mm from the earth line on each lightning conductor (see Fig. 1). They will thus measure the amplitudes of the surge currents from 100 to 10,000 amperes and the pulse durations from 1 to approximately 500 microseconds.

The measurements are interpreted as follows :— Let, for instance, the amplitude obtained with magnetic bar (1) (undamped) be 375 A, corresponding to a magnetising current of 2·5 A in the measuring coil. Bar (2) is also magnetised to the same value ; therefore, the current has lasted longer than 1 μs. Bar (3) is magnetised to 80 per cent of the above value, or damped down 20 per cent. Therefore, the duration of the pulse must have been approximately 25 μs. Bar (4) is not magnetised. The pulse duration was, therefore, much shorter than 100 μs, and this is borne out by the result with bar (3).

Pulse steepness indicator : As already mentioned, the oscillograph tube and time sweep will not give measurements of extremely steep-fronted pulses. The equipment is therefore completed with a pulse-steepness indicator (Fig. 7). This works on the following principle : A capacitance to earth C discharges through the line across the resistance R which is connected to an indicating spark gap ; this self-ionising spark gap is provided with a thin layer of explosive material between the electrodes. The voltage drop across R is proportional to the steepness of the oncoming voltage pulse, and when this exceeds a certain value, the explosive material is detonated and throws the electrodes apart. This indicates that a surge exceeding a given steepness has passed through the indicator. In practice, the capacitance is the distributed capacitance to earth of an aluminium cylinder. The cylinder contains six spark gaps (one only is shown in Fig. 7) which are connected in parallel across the resistor and held by springs at the lower end of the cylinder. In all cases, at least one of the gaps will spark and its electrodes will be thrown apart to avoid secondary ignition in the same gap. The indicator value is adjusted by varying the value of the resistor R. The indicators are used in groups of three, set at 100, 300 and 1000 kilovolts per microsecond, and hung on the transmission lines outside the station, so that they will not be affected by sudden surges due to switching operations.

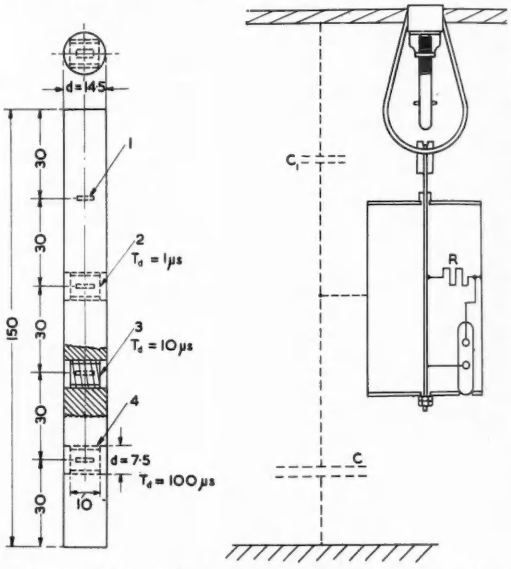

Fig. 6 (left). **Magnetic amplitude and pulse-duration measuring equipment.**

Fig. 7 (right). **Principle of pulse-steepness indicator.**

A number of similar complete measuring stations have been operating for two seasons and have given material including some 200 oscillograms. The equipment has operated satisfactorily in most cases and two-thirds of the lightning surges occurring at the measuring stations have been recorded on oscillograms ; the remaining third were lost, mainly owing to failures in the voltage leads to the oscillograph, which were damaged by the lightning. An example of an oscillogram is given in Fig. 8.

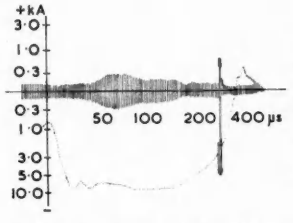

Fig. 8. **Oscillogram recorded at the terminal station of a 70-kV line showing a direct lightning stroke on the line with two discharges in 5 milliseconds.**

Of the approximately 200 oscillograms obtained, about 40 per cent recorded predominantly positive surges and 60 per cent showed predominantly negative surges. About 25 per cent showed more or less oscillatory discharges.

Fig. 9 gives distribution curves of lightning surges

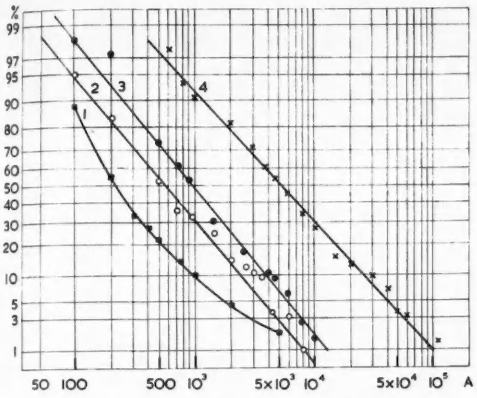

Fig. 9. **Curves showing current-amplitude distributions.**
(1) Swedish measurements in 1948 and 1949 (186 recordings); (2) American measurements of McCann and Beck (current discharges in "station" lightning arresters, 226 recordings); (3) measurements of McCann and Beck ("distribution" lightning arresters, 90 recordings); (4) measurements made in the United States by McCann and Harder (currents in direct discharges, 135 recordings).

and includes results of measurements made in the United States by McCann and Beck. The differences between the two sets of results are attributable to the different measuring equipment used. The American equipment (full chronographs) is of the magnetic type and records discharges for a number of thunderstorms. Our measurements indicate, however, that frequently more than one recording can be taken per thunderstorm. The magnetic bars which we use show an average of 2–2½ magnetisations per measurement, but only that with the highest value is registered. Different climatic conditions may also have an effect. It appears, however, that there are less current discharges through the lightning conductors than in their immediate vicinity.

Regarding half-value times, the average obtained with the equipment described above is 50 μs, with only about 10 per cent of the pulses exceeding 200 μs. Approximately 35 per cent of the recorded surges were on three-phase lines, 15 per cent on two-phase lines, and about 50 per cent on single-phase lines, by far the greater proportion of the high-amplitude pulses being on three-phase lines. It may thus be concluded that the currents passing through the conductors increase with the system voltage per line, and it can be expected that the average value of the current will be 2½ times greater with a system voltage of 70 kV than with 20 kV.

It has been found that steep-fronted surges are a rare occurrence, although the pulse-steepness indicators are apt to record such surges if placed too close to the power station so that they are affected by coupling voltages, which can be extremely steep fronted. For future measurements, the indicators will be situated still further out on the lines. The mean values obtained with the magnetic pulse-duration indicators show close agreement with the oscillograph results, although all measurements of this kind require careful analysis.

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(3) McCann, G. D., and Harder, E. L.: Direct strokes and lightning surges on transmission lines, CIGRE, 1948, Report No. 322

NORWAY

A New Quick-Acting Distance Relay

By H. Hoel. (From *Elektroteknisk Tidskrift*, Vol. 63, No. 28, October 5, 1950, pp. 349-354, 9 illustrations.)

This article gives the constructional details and performance characteristics of a new quick-acting relay for distance protection. The relay operates in 1/100 second and ensures reliable operation under a wide variety of conditions.

This new quick-acting protective equipment has a stepped characteristic and includes separate measuring relays for each step and each phase. There are three steps, which can be adjusted to any required values, and there are, therefore, altogether nine independent measuring units.

In each phase, an additional element is incorporated for re-setting the relay elements to their original positions.*

Fig. 1 shows the stepped characteristic of the relay system. *A*, *B* and *C* are three measuring stations. The relay at *A* works in the opposite direction to *B* and covers almost the entire length of the line *AB*. If the short-circuit is situated on the remaining section of the line *AB* or at a distance up to 30 per cent of the length of the line *BC*, the relay operates with a time lag which is usually about one-half of a second.

If the fault is situated at a further distance in the blocking direction, the third step of the relay system will operate, with a somewhat longer time lag, up to a certain limit.

Fig. 2 shows the impedance diagram of the relay at station *A*, which has the stepped characteristic indicated in Fig. 1. The first step relay operates for all faults situated within the area of circle 1, and switches out instantaneously. The second step reacts to faults within circle 2, etc. The fourth step operates when the short-circuit is cleared, that is, when the impedance vector extends beyond circle 4 or when the line voltage

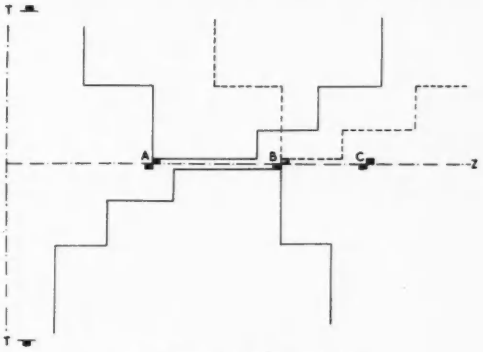


Fig. 1. **Stepped characteristic.**

*See also J. Landmark-Braten: *Elektroteknisk Tidskrift*, Vol. 63, No. 25, Sept. 5, 1950, pp. 309-317.

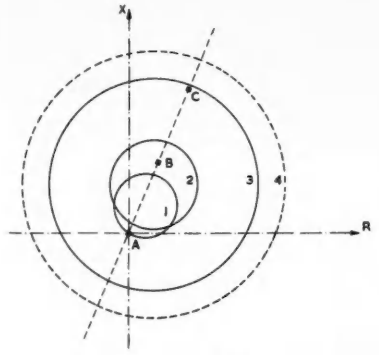


Fig. 2. **Limiting impedance diagram of relay.**

is zero, and then restores the first, second and third step relays to their initial positions. The circle of the second step is arranged so as not to include station *A*, thereby making it possible to dispense with special directional equipment.

The third step is also designed to operate over a certain length in the blocking direction, and is arranged concentrically around the second step. This is achieved by means of pendulum-type breakers. In case of voltage fluctuations along the line, it is not desirable that the relay, which may be measuring a low impedance, should operate, and the relay is therefore blocked for a short period. A detailed description of the equipment is given below.

PRINCIPLE OF A.C. CIRCUIT CONNECTIONS

The circuit diagram shown in Fig. 3 gives details of the connections for one phase and one step of the distance relay control system. Each of the rectifier groups is supplied with voltages which are proportional to the corresponding short-circuit current and voltage. The rectifier currents are compared in the RHc relay, which is designed to operate until the resulting ampere-turns value is equal to zero. With the circuit used, the properties mentioned below are obtained, assuming ideal rectification and complete smoothing :—

(a) The operation of the RHc relay is determined only by the impedance of the short-circuit loop ;

(b) The impedance characteristic in the *R-X* diagram is always of circular shape when two rectifier groups are used ;

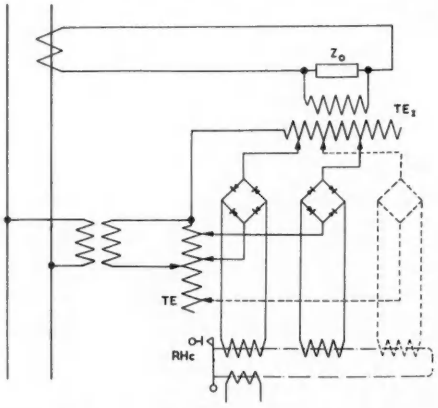


Fig. 3. **Schematic diagram for a.c. circuit.**

(c) Various other curves, and, in particular, elliptical and hyperbolic characteristics, can be obtained when more than two rectifier groups are used ;

(d) The characteristics are determined by adjusting the phase angle of the standard impedances used for comparison and altering the transformation ratio of the transformers *TE* and TE_I.

At present, only two rectifier groups are used for each RHc relay. The first group is connected to TE_I (current) only, and the other is linked up with both RE_I and TE (current and voltage) simultaneously. Measurement accuracy is ensured by arranging that both rectifier groups receive currents of equal amplitude when the RHc relay is operating near its limits. Under these conditions, the impedance characteristic is circular, and the position of the centre of the circle and its diameter can be adjusted as required. The characteristic may also be adjusted so as to pass through the origin of the *R-X* diagram, if necessary. This makes it possible to dispense with the use of a special directional relay.

The influence of the short-circuit current d.c. component on the impedance measurements is strongly reduced by a shunt which gives a comparison impedance Z_o'. The shunt impedance is low in comparison with that of the relay itself. As the relay has a low volt-ampere consumption, the impedance value should be chosen, as far as possible, so as to obtain a low total volt-ampere consumption (5 A for normal current).

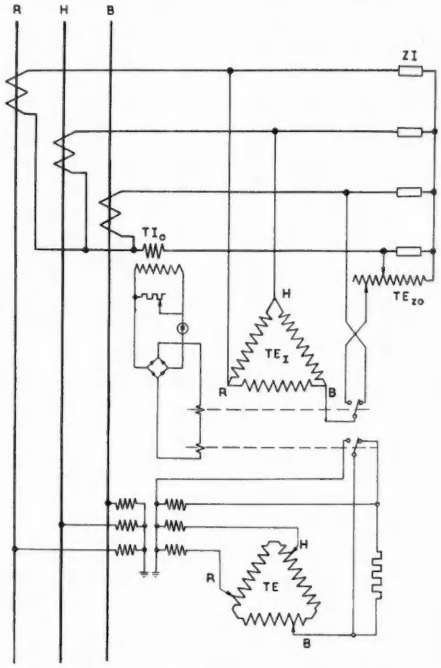


Fig. 4. **Three-phase circuit diagram.**

Fig. 4 shows the three-phase connections of the distance relay primary circuit (the rectifier groups with RHc relays and the secondary windings on TE_I are not shown in this figure). *ZI* is the comparison impedance corresponding to the value of Z_o'. The connections are such that the relay, for instance, with the phase *RS* in a short-circuit, will measure the voltages $I_R' Z_o' - I_s' Z_o'$ and E'_{RS}. Consequently, the relay will give accurate impedance measurements both for two-pole

and three-pole short-circuits. For double earth faults, the relay will measure the voltages $I_R' Z_0' - I_0' Z_{00}'$ and E_{R0} (I_0' = current in neutral conductor, Z_{00}' = corresponding comparison impedance and E_{R0}' = voltage between phase R and earth).

In the case of a double earth fault, with a fault on each side of the relay, the relay connections must be changed over. In such a case it is not only necessary to measure the correct impedance, but also desirable that only one of the distance relays in each circuit between the points of fault should release its breaker. The network is then divided into two parts for each earth fault.

With the aid of the change-over arrangement for earth faults shown in Fig. 4, selectivity is obtained in two-thirds of the short-circuit cases with double earth faults, whereas a number of breakers will act in the remaining cases. However, full selectivity can be obtained by means of an additional arrangement.

As the change-over arrangement shown in Fig. 4 is extremely simple and reliable in operation, switching-over can be carried out under favourable conditions. The two change-over relays for the current and voltage circuits react powerfully to non-symmetrical currents. These relays, similar in design to the RHc measuring units are very quick-acting, since they must act before the measuring relays start operating. After approximately 1·5 cycles of limiting current (switch-over current in neutral conductors), the change-over relays require approximately 1/100th of a second to perform their operation, and for heavy non-symmetrical currents, approximately 1/1000th of a second elapses between the beginning of a double earth fault and complete reversal of the relay.

As previously mentioned, a directional effect can be obtained by suitably adjusting the relays so that the circle characteristic of the first zone in the R-X diagram will pass through the origin. In addition, the arrangement described below is used to obtain a fully reliable directional effect and rapid release in the releasing direction, even if the short-circuit voltage is equal to zero.

In the voltage circuit for the first step, the relay is connected in parallel with an oscillatory circuit, tuned to approximately 50 cps. If the relay has cut off the voltage ahead of the short-circuit, and if this occurs close to the busbars so that the voltage will be zero, the oscillatory circuit will feed the relay in about 1 or 2 cycles. Thus, the relay will reliably determine the direction in which the short-circuiting effects are moving.

In certain cases, the relay has no voltage at the moment a short-circuit occurs, for instance, when connecting up a short-circuited line. If the fault is a two-pole short-circuit, then, as a result of the connections shown in Fig. 4, where each line voltage receives in addition a small portion of the adjacent voltages, a directional effect is obtained even when the short-circuit voltage is also zero. This eliminates the risk of a false release when a two-pole short-circuit occurs close to the busbar zone, which is possible when a slight short-circuit voltage is originated as a difference between two very high voltages which are transformed with some discrepancy in the transformer ratios.

In case of a three-phase metallic short-circuit at the busbars, it is impossible to determine by means of impedance measurements, the direction in which the short-circuit effects are moving, if the relay has no voltage before the fault occurs. This case may arise when switching on to a line where, for instance, a remote earth connection has been forgotten after making repairs. In such cases, it is desirable that the breakers trip automatically as rapidly as possible to avoid effects in the blocking direction. This is obtained by making the relay switch over lightly when the line has no voltage. The switch-over takes place automatically and is such that the circle for the first step is slightly displaced, so that the first zone will include all the faults on the busbars and in their vicinity. This switch-over is then neutralised automatically as soon as the relay receives voltage, and if the voltage drops to zero as the result of a short-circuit, the switch-over will not operate, so that the first zone will not include the busbars.

THE RELAY ELEMENT RHc

The relay element RHc is designed as a fully enclosed unit and consists of a horseshoe magnet with a small armature, which, in its normally deflected position, rests on the core.

The core and the armature are made of very soft iron with low coercive force and high residual magnetism. The armature carries a silver layer separating the iron of the armature from the core. The armature is supported on knife-edges with minimum friction, no oil being used. In the pressed-down position of the armature, the contact is open. A spring tends to lift the armature off the core and thus close the contact.

The core is provided with two coils connected to the two rectifiers shown in Fig. 3 and also has a coil for the restoring action. The residual magnetism of the relay is sufficient to keep the armature pressed upon the iron core under normal operating conditions. When a short-circuit occurs within the zone included in the circuit of the relay, the direction of the resulting ampere-turns is altered, and this requires a certain time owing to the electrical inertia of the system.

The force of the releasing spring is adjusted so that it is nearly equal to the magnetic forces and the armature is released when the ampere-turns are nearly equal to zero. The moment the armature is released from the core, the air gap immediately reaches its maximum value, the residual magnetic forces drop down suddenly, and the armature, which weighs 2 grams, is accelerated upwards with a force of approximately 40 grams. The contact pressure is, therefore, large and is practically independent of the magnitude of the short-circuit effect which acts upon the relay. The releasing period of the armature is very small, viz., approximately 0·001 sec.

The relay element providing the restoring force is similar in design to the relay just described, but contact is made when the impedance increases above a certain value determined by the adjusted characteristic for the fourth step. The contact also closes automatically when both the current and the voltage are equal to zero. This restoring relay is ready to operate as soon as one or more relays of the other steps have closed their contacts.

The RHc relay element is very light, but of extremely robust construction. It is provided with a pin-type socket for plugging into a corresponding holder, and is therefore easily removable for overhaul or inspection.

TIME RELAYS

The time relays used for controlling the release of the second and third step relays are also of the RHc type, but have only two windings. The schematic circuit diagram for these relays is given in Fig. 5. The first coil, known as the "operating coil," is connected to a potentiometer and has no applied voltage under normal operating conditions. The second coil, known as the "retaining coil," is normally subjected to an applied voltage and keeps the armature in the deflected position. When switching begins with the aid of the impedance-measuring relay, both coils are disconnected from one pole of the battery. The condenser discharges gradually, through the retaining coil, across a large series resistor. The ampere-turns of the two coils act in opposition. The current discharge from the condenser falls off exponentially and after a certain time the ampere-turns of the retaining coil reach a value which is lower than that of the ampere-turns of the

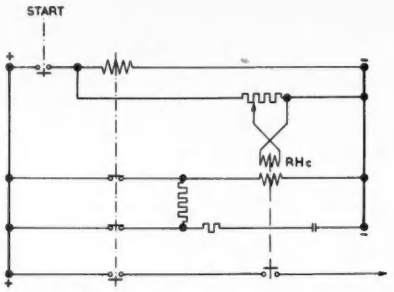


Fig. 5. **Schematic circuit diagram of time-measuring relay.**

operating coil, with the result that the armature is released and the contact closes. The releasing time is easily and accurately adjusted by means of a regulating potentiometer. The adjustment range is from 0·2 to 3·0 sec., and the amount of scatter in the actual operating range, for instance, that of the time relay of the second step, does not exceed $\pm$ 1 per cent.

PENDULUM BREAKERS

The distance relay equipment includes two types of pendulum breakers, viz., an impedance pendulum and a time pendulum breaker. During one swing of a pendulum, the impedances of all the phases generally fall off comparatively slowly at first. This causes all the relay elements of the third step to operate an instant before those of the second step. If this time difference between the starting of the third and second steps exceeds approximately 5/100 second, the impedance pendulum breakers block the releasing circuits of the first and second step systems for an adjustable period of time. The third step is not blocked, since its releasing time is so long that this measure is unnecessary. The second and third step circle characteristics remain concentric when the pendulum breakers are used, as shown in Fig. 3.

In many cases, a pendulum may swing for a number of cycles, with a gradually increasing frequency, and if the time differences between the starting of the third and the second step are less than 5/100 sec., the impedance pendulum switches may no longer operate. The time pendulum breakers then come into action, provided there is another impedance drop, one or more cycles after the impedance pendulums first start operating. If, however, the distance relay starts working again within a certain period of time after having gone back to its original setting, the releasing circuits for the first and second steps are automatically locked so that there will be an accurate time difference between the relays of the third and second zones. The pendulum breakers will lock the release gear of the entire system if the impedance decreases in all three phases and remains accurately symmetrical. The time pendulum units cannot lock the release gear before the impedance breakers have reacted, and there is, therefore, no risk that they will lock after the operating breakers are connected, so that it will not, therefore, be necessary to put them out of operation under normal switching conditions. If the pendulums swing as a result of a two-phase short-circuit after a relay has been reset or has gone over to a double earth fault, the locking devices are neutralised immediately.

SIGNALS

The distance relay is provided with a centralised signalling system. There are separate signals for each releasing circuit, i.e., for the first, second and third steps. Furthermore, signals are used on each phase to indicate the beginning of the second and third step, respectively. In addition, there are signals for connections to earth on the pendulum breakers.

The signals used are electromechanically operated. Each unit is built in a cylindrical case, which is covered with a glass plate painted in brown, except over the parts of the surface where letters or numbers appear. The glass plate is fitted over a soft iron disc painted yellow. When the disc lies directly against the brown glass plate, the yellow symbols are clearly visible as a result of the light reflected from the yellow disc, whereas when the disc is pulled back against the magnet core, the symbols disappear, since less light reaches the yellow disc and is reflected from it. The iron disc is normally pulled back against the iron core, owing to the residual magnetism of the latter, which is stronger than the spring force which seeks to push the disc forward against the glass. The signals are cleared by sending a powerful d.c. pulse through the coils of all the signals, by pressing a push-button on the relay control panel.

The distance relay is also fitted with various other signalling devices. A counter unit indicates the number of cycles which has elapsed since the relay started operating, for instance, under pendulum action, and another counter shows whether the relay elements have been switched on. Furthermore, the relay is provided with three signal lamps. The first lamp lights up to show that the d.c. supply to the relays is in order. Lamps 2 and 3 light up in case of failures of the time relays of the second or third step systems.

ADDITIONAL EQUIPMENT

The distance relay is designed so as to be able to include, if desired, the use of the following additional equipment :—

(a) Equipment for conversion to high-frequency control of the distance relay operation enabling a decrease in the releasing time of a short-circuited line, regardless of the position of the failure ;
(b) arrangement for single-pole disconnection of the operating breakers ;
(c) automatic switching equipment, with automatic variation of the relay impedance characteristics.

MAIN RELAY SPECIFICATION DATA

Release time for the relays of the first step :—

Generally, the release time is determined by the smaller of the following ratios :—

$$I_k Z_1/E_n \text{ and } I_k/I_{k\max},$$

where I_k = short-circuit current, Z_1 = total circuit impedance included in the zone of the first step, and E_n = a value between the times $T_{\max}$ and $T_{\min}$ which is given by the short-circuit current for short-circuits with an impedance Z_1.

Within a range of 70 per cent of Z_1 the release time will vary between the values $T_{\max}$ and $T_{\min}$ as given below :—

$I_k Z_1/E_n$ or $I_k/I_{k\max}$ =	0·07	0·15	0·30	0·60	
$T_{\max}$ =	75	55	30	20	millisec.
$T_{\min}$ =	35	22	12	7	,,

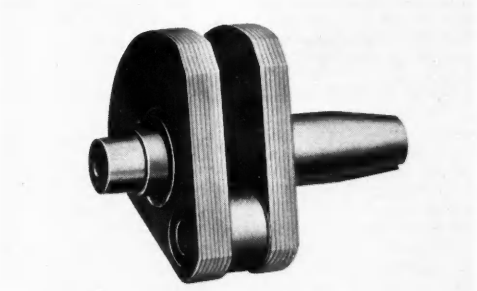
Discrepancies in impedance measurements. The maximum error in impedance measurements for metallic short-circuits is approximately 5 to 10 per cent when either $I_k Z/E_n$ or $I_k/I_{k\max}$ is greater than 0·07.

Range of adjustment. The adjustment for maximum impedance is limited by the load capacity of the line, i.e., the lowest load impedance. The lowest impedance for which the relay can be adjusted is less than the value determined by $I_k Z/E_n = 0{\cdot}05$, where Z is the minimum impedance of the loop. The size of the circle diagram characteristics can be adjusted for all phase directions between approximately 15 deg. and 65 deg. and also for approximately 0 deg.

New Materials, Processes and Equipment

COPPER-BRAZED CRANKSHAFTS

Copper-brazed crankshafts, with components made on punch press and screw machine, can frequently replace drop-forged construction without sacrifice of quality and with substantial cost reduction. Operating characteristics are sometimes better than those of conventional design.



These shafts, hardened or unhardened, made to customer's specifications, are offered by Technical Metal Processing Inc., Cleveland 14, Ohio.

SPUN AND BRAZED MAGNESIUM TUBING

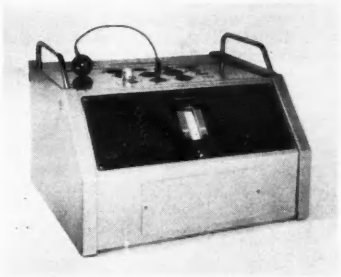
For many years the Joyce-Cridland Co., Dayton, Ohio, producers of hydraulic lifts, had sought a lightweight float that would function indefinitely without corrosion, although it was to be used in pits where corrosive conditions often prevail and where servicing is extremely difficult. Many metals were tried, including several copper alloys, but the high specific gravity of the alloys necessitated the use of thin-walled stock, and occasional failures occurred.

It was finally decided to try a magnesium alloy, with which a $\frac{1}{16}$ in. side wall and a thicker bottom could be permitted. Magline Inc., Pinconning, Mich., undertook the job and, using both spinning and brazing operations considered unusual in the working of magnesium, is now successfully mass-producing the floats. In a subsequent operation at another plant, the float is plated—another uncommon procedure in the manufacture of magnesium products. Substantial coats of zinc, copper and cadmium are applied, and the final coat is given an Iridite treatment. The final result is considered highly satisfactory.

HIGH-SPEED VALVE TESTER

A new automatic valve tester, specially adapted to meet the need for quick, accurate valve testing by non-technical personnel in communications and radar establishments and industry, has been introduced by the Equipment Division of Mullard Electronic Products Limited. The instrument is specially noted for its speed and simplicity of operation, and should result in a notable saving in trained technical staff. It should also prove a great aid to service engineers in diagnosing faults in complicated electronic equipment.

The new instrument is provided with a cathode-ray tube and a coloured scale for visually indicating the condition of the valve under test. If the valve is within the specified limits, the spot on the screen is deflected to the green part of the scale. If, on the other hand, the valve fails to meet the test requirements, the spot is deflected to the red part of the scale. A reading in the intermediate yellow portion of the scale indicates that the valve, although still giving reasonable performance, will probably need early replacement.



The valve tester is compact and solidly constructed, and all internal components are readily accessible for servicing by removing one or more sections of the case. The top panel carries a complete range of valve holders to accommodate all current types of valve.

PRECISION ELECTRONIC COUNTER TACHOMETER

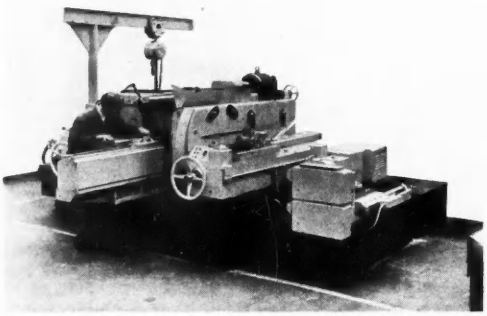
The Potter Instrument Company, 115, Cutter Mill Road, Great Neck, N.Y., announces a new high-speed electronic counter tachometer for high-accuracy revolution and frequency measurements. Fundamentally, the instrument totalises the number of counts derived from the source being measured during a precisely established time interval of 0·6 second. This reading is displayed on a direct-reading, four-digit electronic counter using ten neon glow lamps for each digit. After each measurement and display period, the instrument automatically resets and recycles. The display time is adjustable over a period of from 0·5 second to 4 seconds, or can be set to hold the count indefinitely.

The instrument can be used to measure frequencies up to 100,000 cycles per second with an accuracy of ± 1 cycle. In addition to the electronic counter registration of the measured frequency, the unit also includes a count rate meter which can be used when the unknown frequency source is being adjusted. This type of indication reflects instantaneous changes and is useful when the source of frequency must be manually adjusted to a specific point.

Because the instrument is direct-reading and requires no adjustments or interpolation of results, it is ideal for laboratory and production frequency measurements.

LARGE CENTRELESS GRINDERS

The production of the new Scrivener No. 4 centreless grinding machine marks a distinct stage for the machine-tool industry of Great Britain in that it is the largest machine of this class produced either in England or in the United States. In the past, machines of this size and type have only been procurable from one continental source, so that the development of this No. 4 will help to liberate users from a too exclusive reliance upon a single country of supply.



The vast majority of the very large centreless machines of this type have hitherto been supplied mainly for such heavy work as bar grinding by the straight-through method. In the case of the Scrivener machines, however, the field into which they are mainly entering is that of form ground work by the in-feed method, as the wide wheel that can be mounted (up to 20 in.) enables such long work as a 19½ in. textile spindle comprising four tapers and a parallel portion to be ground all over in a single operation.

The machine illustrated operates upon the well-known controlled-cycle principle. Speed of the grinding wheel is 950 rpm and the power of the main motor is 35 bhp. There are six control wheel speeds and an extra high speed used only for diamond-truing the wheel.

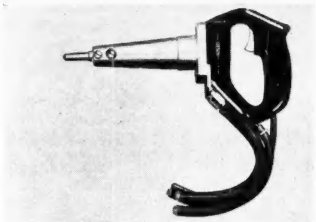
MOLYBDENUM-BASE LUBRICANT

Several new forms of molybdenum-base lubricants have been announced by the Lockrey Co., College Point, N.Y. One of these is a specially treated compound of molybdenum which has the property of attaching itself to metal-bearing surfaces by molecular attraction, thus forming a lubricating film which can withstand extremes of temperature and pressure. Molybdenum is incorporated in a volatile liquid which serves to transport the metallic lubricant to the bearing surface. There it evaporates, leaving a plating of molybdenum which results in a dry but well-lubricated bearing. It can be used, for instance, as a lubricant in the hot extrusion of steel at 2,500° F where bearings are run continuously at red heat without affecting its lubricating qualities.

Molybdenum-base lubricants are also manufactured in non-volatile liquid form. These types remain liquid at all temperatures and are suitable for applications where a circulating cooling effect is required.

RIVET GUN

A Rivet Gun using Du Pont explosive rivets for high-speed operation in blind, inaccessible spots has been announced by Ripley Company, Inc., of Middletown, Conn. Eliminating the need for back-up, no hammer or bucking bar is required. Only a single



touch of the gun (less than 2 seconds), and the rivet is set. Light enough for women workers, one person can do the work of two. The tips are made of nichrome steel welded to a bronze base. The handle consists of two-piece phenolic, in which is located a handy off-on switch for easy manipulation on heavy production work.

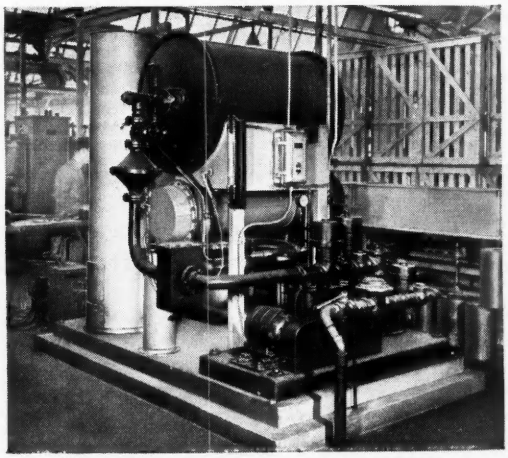
CONTINUOUS BRIGHT BRAZING FURNACE

A 100 kilowatt G.E.C. Mesh Belt Furnace for the bright brazing of assemblies, including the shell for the sealed refrigerator compressor unit, has been installed at the plant of Coldair Ltd.

The parts are assembled with the necessary brazing material and are then placed on the 16 in. wide wire conveyor belt. The belt is of small mesh and is carried on large diameter drums. The tension of the belt is automatically adjusted to compensate for the expansion and contraction between working and closed-down periods.

The heating chamber is divided into two sections, the temperature of each of which is independently and automatically controlled. By this means, an accurate rate of heating for the work can be provided with heating times which can be varied by adjusting the speed of the conveyor belt.

A feature of the furnace is the provision of a water-jacketed cooling zone at the outgoing end. By means of this, the work is cool enough for direct handling when it leaves the furnace. This cooling zone is of value in relation to continuous production plans, as no special handling equipment is required and operators need have no doubts as to whether assemblies are too hot to touch. Brazing is carried out in an atmosphere of partially-burnt town gas and air, supplied by a G.E.C. controlled



atmosphere plant, shown above. The atmosphere used is non-oxidising and it is desulphurised before being admitted to the furnace. The furnace has an overall length of 50 ft 6 in. and gives an output of 30 assemblies per hour.

Machine Shop Practice—*continued.*

Tool and grinding marks as well as intersecting surfaces can be blended, reducing the number of potential starting points for small cracks.

Fineness of the finish is determined by the type of brush and auxiliary compound used. The action of brushing is that of blending surface irregularities rather than actual removal of metal. Through variation of the gauge of the brush fill wire and other brush material, it is usually possible to adapt them to all metals. Special brushes with fibre fill are also efficient for burr removing and are frequently used on precision parts where the finish of adjacent surfaces must be maintained or improved. These brushes must be used especially on ductile metals, such as stainless steel, in those cases where the brushing action of wire brushes will peen the burr instead of removing it.

Rotatating Disc Cutting Tool for Machining Cylindrical Surfaces

By A. V. ZHIVCHIKOFF. (From *Stanki i Instrument, Russia*, No. 7, 1950, pp. 21-22, 5 illustrations.)

A NEW method of turning is proposed, in which the cutting edge of the tool is formed by the periphery of a rotating disc. The arrangement is illustrated in Fig. 1. The main feature of the rotating disc cutter, as compared with the conventional prismatic tool, is the great reduction in friction between the tool and the work.

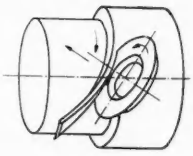


Fig. 1

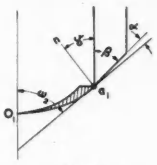


Fig. 2

The lip angle of the circular cutting disc depends on the depth of cutting and on the end relief angle. It is determined as follows. If, in Fig. 2, a_1 O_1 is the curve along which the cutting edge of the tool travels relative to the work, and if β is the lip angle of the disc,

$$\tan \beta = \tan \beta_2 / \cos \varphi$$

where $\beta_2 = \omega_2$ minus 2 to 3°; φ is the "contact" angle between tool and work, determined from:

$$\cos \varphi = (R - t)/R$$

where R = radius of cutting disc, and t = depth of cut. ω_2 is determined by the formula:

$$\tan \omega_2 = \frac{R \sin \varphi \cos \alpha}{t + R\left(\frac{1}{\cos \varphi} - 1\right)}$$

where α is the end relief angle.

The following advantages are claimed for the new cutting tool when compared with the conventional tool:

(1) The flow of the chip is not obstructed by the bulk of the work. Consequently, the energy of deformation of the chip and the friction between chip and tool is reduced.

(2) The cutting depth of the rotating disc is a fraction of the actual cutting depth (see Fig. 1).

(3) Under otherwise identical conditions, the relative cutting velocity is smaller.

(4) Less heat is developed.

Experiments under actual production conditions have shown so far that the new tool is suitable for light and heavy cuts on smooth external and internal cylindrical surfaces.

METALLURGICAL ENGINEERING

Oxidation Phenomena and Local Temperature Rise During Machining in Vacuo

By R. COURTEL. (From *Revue de Métallurgie, France*, Vol. 47, No. 9, September 1950, pp. 700-703, 7 illustrations.)

THE heat imparted to a work piece by machining leads sometimes to crystalline changes (e.g., in cobalt), and sometimes to oxidation phenomena, which can best be observed if machining is carried out by milling at very low air pressures inside the vacuum chamber of an X-ray diffraction unit. Diffraction patterns by the Debye-Scherrer method, when taken perpendicularly to the direction of milling on an 80-20 nickel-chromium alloy, show that only traces of oxides (NiO plus Cr_2O_3) develop when the milling speed is 75 fps or less. A strong formation of Cr_2O_3, on the other hand, is discovered after milling at 92 fps, or more. A similar, though much less distinct, threshold value is observed for NiO at milling speeds of about 50 fps. Comparative slow heating tests show that local surface temperatures must have reached 400° C at milling speeds of about 50 fps, and 550 to 600° C at about 80 fps. The crystalline changes observed in cobalt, a metal of similar machinability but much lower thermal conductivity, also prove that a surface temperature of 400° C is reached at milling speeds of 50 fps. Moreover, these crystalline changes persist after cooling, this being an indication of a vigorous quench. Tests therefore lead to the conclusion that the temperature rise is strictly localised and instantaneous, the highest temperature being reached in a fraction of a second. A similarly instantaneous temperature drop follows, caused by heat conduction in the metal. The experimental methods used by the author may well lend themselves to further investigations of oxidation phenomena and other chemical reactions.

WELDING

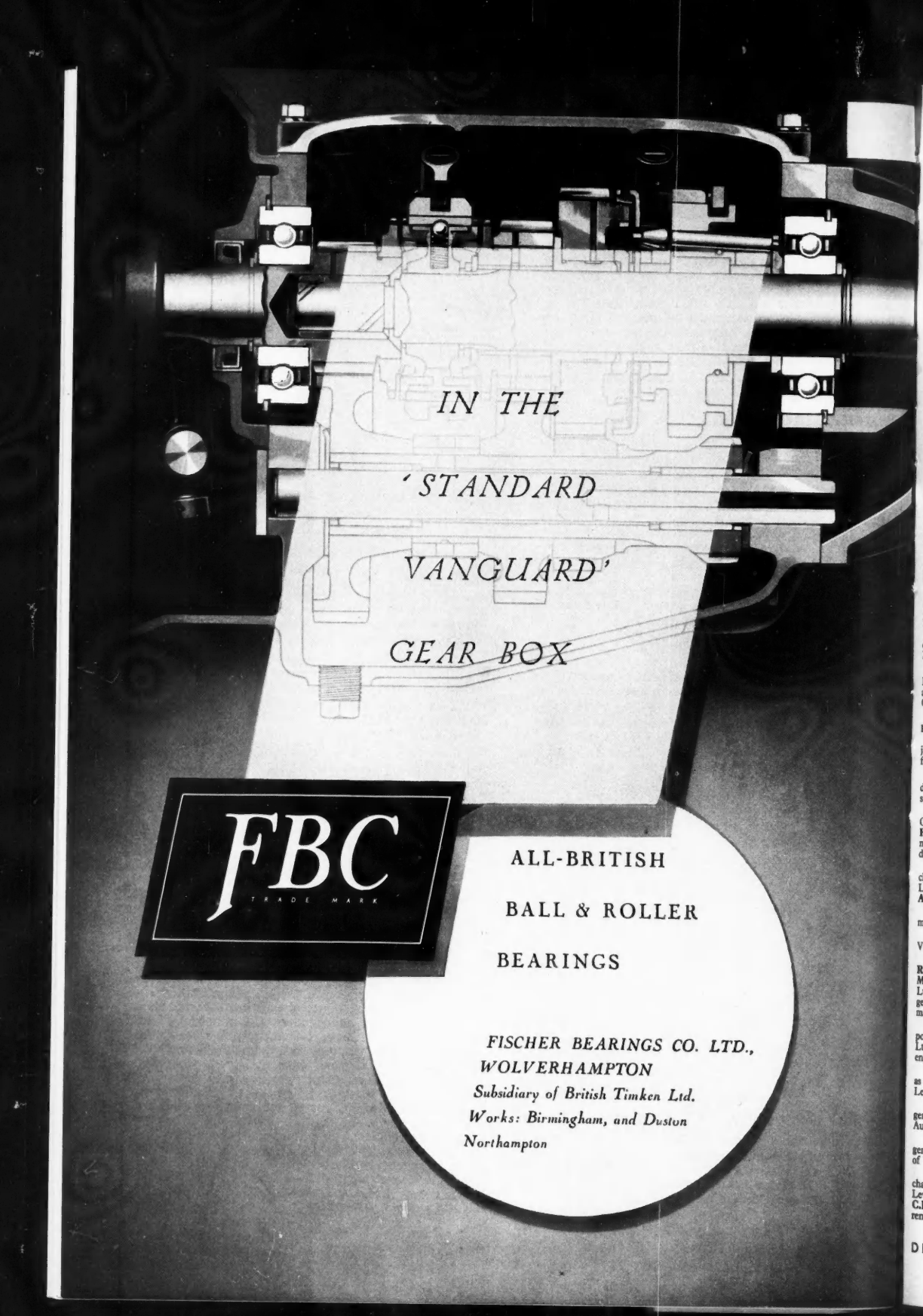
Welding Air-Hardening Alloy Steels

By W. H. WOODING. (From *The Welding Journal, U.S.A.*, Vol. 29, No. 11, November, 1950, pp. 552-564, 16 illustrations.)

THE investigations of various procedures for the shielded metal-arc welding of an air-hardening alloy steel indicated that the isothermal-transformation characteristics of the heat-affected zone considerably influenced the weldability of the material under high restraint. The restraint imposed required utilisation of preheat and interpass temperatures exceeding that temperature at which the martensite transformation begins on cooling the material from the austenitising temperature. At such preheat and interpass temperatures, it was found that satisfactory restrained welds could be obtained only by maintaining the temperature as a postheat for a suitable length of time. When the scarf surfaces were clad with weld metal prior to the deposition of the butt weld and the accompanying restraint, satisfactory welds were obtained at a relatively low preheat and interpass temperatures.

These observations led to a study of the isothermal-transformation characteristics of the heat-affected zone of single-pass welds deposited on this material. The results indicated that above the temperature at which the martensite transformation begins, the heat-affected zone is very sensitive to thermal shock and prone to underweld cracking. This cracking persists until the bainite transformation approximates 8 per cent. Heat-affected zones exhibiting partial martensite transformation are likewise sensitive to underweld cracking unless they are subsequently tempered prior to thermal shock.

Studies of the effect of preheat upon cooling rates of heat-affected zones indicated that the initial cooling rate resulting from the quench effect of the base plate was not materially retarded by increases in preheat temperature.


IN THE
'STANDARD
VANGUARD'
GEAR BOX
FBC
TRADE MARK
ALL-BRITISH
BALL & ROLLER
BEARINGS
FISCHER BEARINGS CO. LTD.,
WOLVERHAMPTON
Subsidiary of British Timken Ltd.
Works: Birmingham, and Duston
Northampton

NEWS OF THE MONTH

PERSONAL

Mr. Denis W. M. Allen has been appointed a director of W. H. Allen, Sons & Co. Ltd., Bedford.

Mr. Frank W. Bell, A.M.I.Mech.E., has been appointed an additional managing director, to act jointly with **Mr. W. T. Bell,** chairman and managing director of Robey & Co. Ltd., Lincoln.

Dr. H. E. Davies has been appointed metallurgist to the British Electricity Authority.

Mr. Charles Connell, M.A. (Cantab.), M.I.N.A., has been elected President of the Shipbuilding Employers' Federation, 1 Chester Street, London, S.W.1., in succession to **Sir Laurie Edwards, M.I.N.A. Mr. A. L. Cochrane, M.I.N.A.,** has been elected senior vice-president, and **Mr. J. G. Stephen, M.C., M.I.N.A.,** and **Mr. T. Eustace Smith, T.D., J.P.,** have been elected vice-presidents. **Mr. G. C. Parker, M.I.N.A.,** has been elected chairman, and **Mr. Robert Cousland, M.I.N.A.,** vice-chairman of the Conference and Works Board.

Mr. O. E. Dickinson, A.M.I.Mech.E., has been appointed managing director of Smith Brothers & Co. (Hyson) Ltd., Nottingham.

Mr. R. W. Dunn has been appointed chief engineer at the Basingstoke works of Kelvin & Hughes Ltd.

The Bessemer Medal of the Iron and Steel Institute for 1951 has been awarded to **Mr. Ben Fairless,** President of the United States Steel Corporation, in recognition of his distinguished services to the steel industry.

Mr. L. Gaiger has been appointed sales manager, and **Mr. John Muirhead,** assistant sales manager of the Aerograph Company Ltd., Lower Sydenham, London, S.E.26.

Mr. C. S. Gill, managing director of Davy and United Roll Foundry Ltd., Middlesbrough, has been re-elected chairman of the Roll Makers' Association of Great Britain for the fifth successive year.

Mr. G. E. Gordon Hope-Johnstone has been appointed sales director, and **Mr. J. A. J. Nicholas,** general sales manager of the Regent Oil Co. Ltd., 117 Park Street, London, W.1.

Lieut.-Col. S. J. L. Hardie, D.S.O., LL.D., chairman of the Iron and Steel Corporation of Great Britain, has resigned his appointment as a part-time member of the British Transport Commission.

Mr. R. F. Harvey has been appointed chief officer (motive power) to the Railway Executive.

Mr. D. Lacy-Hulbert, B.Sc., A.R.I.C., has been appointed joint managing director of the Chesterfield Tube Co. Ltd., Chesterfield, a subsidiary company of Tube Investments Ltd.

Mr. R. G. Ledger and **Mr. K. F. Dormer** have been appointed directors of Mackay Industrial Equipment Ltd., Feltham, Middlesex.

Mr. S. E. Osborn has been appointed chairman of Samuel Osborn & Co. Ltd., Clyde Steel Works, Sheffield 3. **Mr. F. A. Hurst** has been appointed deputy chairman and will continue as managing director, and **Mr. B. C. Pye-Smith** has been appointed director.

Mr. R. A. Park, A.M.I.E.E., has been appointed engineer-in-charge, power supply division, Brush Electrical Engineering Co. Ltd., Loughborough, and **Mr. H. Du V. Ashcroft, B.Sc., A.M.I.E.E.,** engineer-in-charge, industrial division.

Mr. G. M. C. Peacock, A.M.I.E.E., has been appointed manager of the Publicity Department of Babcock & Wilcox Ltd.

Mr. R. M. Robson has been appointed managing director of Vaughan Brothers (Drop-Forgings) Ltd.

Mr. W. J. Ruston has been elected chairman, and **Mr. Harold Riggall** deputy chairman, of Ruston & Hornsby Ltd., Lincoln. **Mr. E. R. Jones** has been appointed a director of Ruston-Bucyrus Ltd. **Mr. J. R. Bergne-Coupland, J.P., M.I.P.E.,** works manager, and **Mr. T. L. Kendall, M.I.Mar.E., M.I.N.A.,** marine manager, have been elected directors.

Mr. Matthew Seaman, M.I.Mech.E., has relinquished his position as director and general manager of David Brown-Jackson Ltd., Manchester, on being appointed general manager of the engineering works of the British Oxygen Co. Ltd., Edmonton.

Mr. K. F. Starling, B.A. (Cantab.), has taken up his position as mechanical engineer to Canadian-Brazilian Services Ltd., 148 Leadenhall Street, London, E.C.3.

Mr. L. W. Stretton, M.I.E.E., has been appointed chief generation engineer (operation) Eastern Division, British Electricity Authority.

Mr. C. Stephenson, A.M.I.N.A., has been appointed shipyard general manager, and **Mr. J. G. Hugall** has been elected a director of William Doxford and Sons Ltd., Pallion, Sunderland.

Captain R. E. F. De Trafford, O.B.E., has been elected chairman of Elliott Brothers (London) Ltd., Century Works, Lewisham, S.E.13, in succession to **Sir Walter St. David Jenkins, C.B, C.B.E.,** who relinquished his position of chairman, but is remaining on the Board.

Mr. L. C. W. Turner has been appointed manager of the Plant Division of Crompton Parkinson Ltd., Manchester, and **Mr. A. G. Graham, A.M.I.E.E.,** manager of the firm's Plant Division at Belfast.

Mr. D. P. Welman has resigned his office as managing director and member of the Board of Foster Yates and Thom Ltd., on becoming chairman of the North Western Gas Board. **Mr. R. Lucas** has been appointed director and general manager, and **Mr. H. Dowell, A.M.I.Mech.E.,** technical director of the Company.

Mr. J. W. Wicks, M.I.Mech.E., assistant engineer (development), 'buses and coaches, Chiswick Works, London Transport Executive, has taken over the responsibility for tramway and trolleybus design and development, rolling stock contracts and inspection. **Mr. J. Schofield, M.C.,** works engineer (trams and trolleybuses) has taken over responsibility for the Fulwell Works.

DIESEL LOCOMOTIVE MANUFACTURING

The Productivity Team from the Diesel Locomotive Manufacturing Industry, which visited the U.S.A. in the early part of this year, makes far-reaching recommendations in a Report published by the Anglo-American Council on Productivity, 21 Tothill Street, London, S.W.1.

The Team has kept in mind two factors of the first importance that have been favourable to American manufacturers—(1) the large and " ripe " home market and (2) a single standard gauge of track, a generous loading gauge and heavy permissible axle loading. The British industry cannot rely on a large home market in view of the fact that British railways manufacture their own locomotives, and is therefore forced to rely to a far greater extent than the American industry on export markets, with their great variety of gauges and operating conditions. Yet the British industry will benefit from a review of American manufacturing practices.

The recommendations are :

Design staffs should aim at the principles of UNIT CONSTRUCTION and an immediate close study of the subject should be undertaken.

A simple form of departmental budgetary control should be

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introduced, where it does not already exist, as a first step towards creating the cost consciousness which is an essential step towards greater productivity.

Management in Britain should seek the opportunity to see at first hand American management in action because the American attitude to managerial responsibility has such an important bearing on productivity. It is unreasonable to expect from organised labour the sacrifice of long-standing principles unless management gives a lead by putting into effect the lessons to be learned from such a study.

Consideration should be given to the abolition of piecework and the substitution of an enhanced hourly rate, with time study, in order to establish agreed standard times.

If the simplification of methods recommended in the Report is achieved, craft trades and trade apprenticeship, as at present known in Britain, should be abolished.

A more enterprising approach should be made by design staffs to what may appear to be the unorthodox, coupled with a better appreciation of the problems confronting manufacturing departments.

Young British engineers should be sent to work in American plants for a year or so to absorb a knowledge of American principles and the technique of collaboration between design and workshop staffs.

Drawing-office staffs should be reorganised into groups to facilitate the flow of work and to free senior members of the staffs for closer contact with manufacturing departments.

Sales and service staffs should be convinced of the vital part they must play in the general drive towards increased basic standardisation and greater productivity.

As many members as possible of sales staffs should have technical experience and training.

Better prospects should be offered to planners, rate-fixers, time study men and progress personnel in order to attract the type of man without whom the desired degree of efficient production control cannot be attained.

Better routing of all materials by every form of internal transport should be introduced; and there should be a regular study of flow charts.

Shortage lists should be eliminated and schedules substituted which are really to be kept.

A higher percentage of better supervision should be introduced.

A close and more personal relationship should be fostered between management and foremen and a fuller interchange of all information affecting production.

A bolder approach should be made to welding by the use of heavy gauge electrodes and flame-cutting to finished dimensions without subsequent machining.

More attention should be paid to space heating and ventilation of shops.

All these recommendations have supporting sections in the Report.

NEW G.E.C. EQUIPMENT FOR CARBO-NITRIDING.

The General Electric Co. Ltd. announces that in keeping with its practice of specializing in all heat treatment processes, complete installations for the new carbo-nitriding process can now be supplied.

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In comparison with gas carburising, the case has a greater resistance to wear and less distortion occurs because lower treatment temperatures are used. The nitrogen increases the degree to which the case can be hardened and for certain applications permits the use of plain carbon steels in place of alloy steels.

Details of the new equipments can be obtained from the Process Heating Dept., The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2.

THE IRON AND STEEL INSTITUTE.

The Fifth Hatfield Memorial Lecture, on "Turbine Problems in the Development of the Whittle Engine," will be delivered by Air Commodore Sir Frank Whittle, K.B.E., C.B., M.A., D.Sc., F.R.S., on February 20th, at 8.30 p.m. in the York Hall, Caxton Street, London, S.W.1. The Chair will be taken by Sir Andrew McCance, LL.D., D.Sc., F.R.S., Past-President.

The Symposium on High-Temperature Steels and Alloys for Gas Turbines will take place on February 21st and 22nd in the Lecture Theatre of The Institution of Civil Engineers, Great George Street, London, S.W.1. The Sessions will begin at 10 a.m. and 2.30 p.m. on each day. Non-members of The Iron and Steel Institute will be welcome at the meetings and functions and to contribute to the discussions.

Members of the Symposium Organising Committee are :—Mr. D. A. Oliver (Chairman), Professor G. Wesley Austin, O.B.E., Mr. H. H. Burton, Mr. T. Dennison; Mr. F. Saniter, Dr. H. Sutton, Dr. C. Sykes, F.R.S., and Mr. K. Headlam-Morley.

CHANGE WHEEL GEARING

REPRINT NOW AVAILABLE

Reprints of the article "Change Wheel Gearing," by O. Lichtwitz, M.I.Mech.E., are now available. Originally published in this journal in six instalments from January to June, 1950, the article has met with considerable interest among our readers. We have, therefore, decided to reprint it as a ready-reference work for all those concerned with change wheel gearing problems.

New readers of this journal may be interested to know that the treatise deals with various problems encountered in change gears. Some mathematical fundamentals required for their computation are condensed in a preparatory chapter, thus avoiding any break of sequence in the following sections, which deal with the computation proper. The method developed in these sections makes it possible to find gear trains with any specified accuracy, or to find the best solution obtainable with a given set of change wheels. It has frequently been found, after a gear train has been calculated, that it could not be mounted. The author demonstrates how a proper arrangement of the gears can readily be obtained without resorting to trial-and-error methods, and how such an arrangement, at the same time, ensures the least possible tooth loading.

Indexing when cutting multiple threads in a lathe introduces additional demands on the gear arrangement, and these problems are also dealt with.

The concluding chapter is devoted to the gearing of machine tools and contains ready-for-use tables for screw cutting, including metric and worm threads, which are often found to be troublesome.

An abridged factor table, which, however, meets the most exacting requirements, makes this booklet self-contained. A great number of examples from practice are worked out, and these should prove to be useful as a guide.

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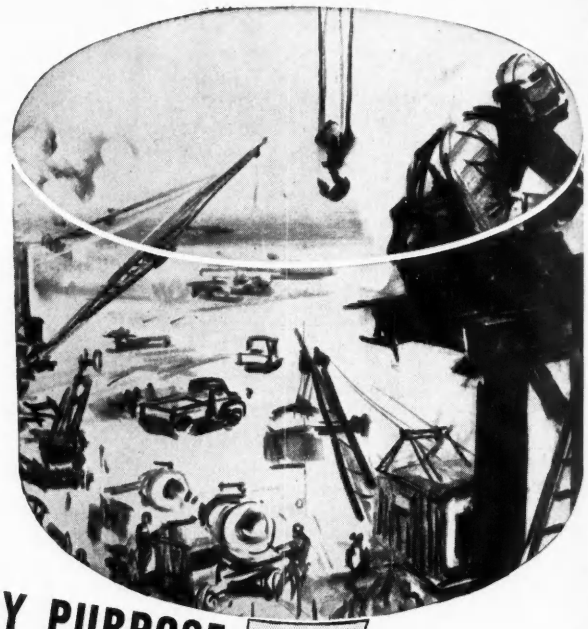

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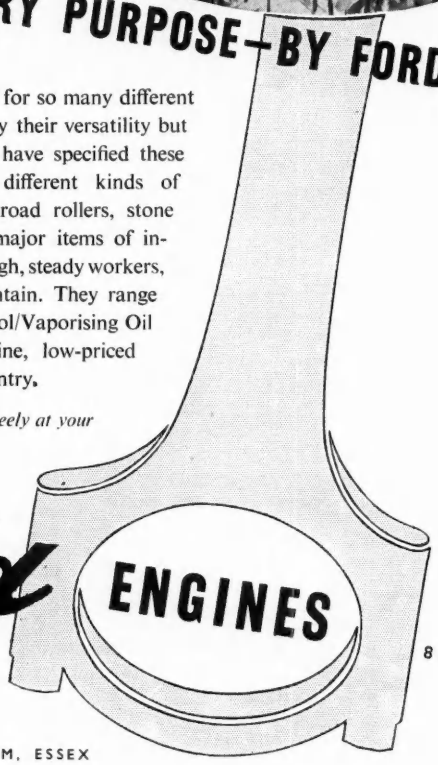

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The Institution of Naval Architects and the Institute of Marine Engineers, in association with the Institution of Engineers and Shipbuilders in Scotland and the North-East Coast Institution of Engineers and Shipbuilders are arranging to hold an International Conference of Naval Architects and Marine Engineers during the Festival of Britain in 1951. The dates of the Conference are June 25th to June 30th in London, July 2nd to July 4th at Glasgow, and July 4th to July 6th at Newcastle upon Tyne. A provisional programme has been arranged including official receptions, luncheons, dinners, and the following papers are to be read :—

" Ship Structures : A Century of Progress," by R. B. Shepheard ; " Ship Motions," by John C. Niedermair ; " Proposed Design for a Special Research and Training (and ultimately Cargo) Ship," by Professor Ir. H. E. Jaeger and Ir. J. C. Arkenbout Schokker ; " Some Aspects of Pre-Fabrication in Ship Construction," by Nils Eckerbom ; " U.S. Fleet Maintenance and Battle Damage Repairs in the Pacific during World War II," by Captain Ralph K. James, U.S.N. ; " Boiler and Turbine Testing," by Captain (E.) L. F. Ingram, R.N. ; " Higher Steam Conditions for Ships' Machinery," by Mark L. Ireland, H. W. Semar, and N. L. Mocher ; " Marine Fuel Oils," by M. Blanchier ; " Stresses in Propellers and Propeller Shafting under Service Conditions," by S. F. Dorey, D.Sc., F.R.S.

BUSINESS NOTES

The White's Marine Engineering Co. Ltd., Hebburn-on-Tyne, whose interests were recently acquired by Durham Chemicals Ltd., is contemplating the purchase of two acres of factory space adjoining the present works in order to double factory area and production. The production of both marine and general engineering products, including loaders, conveyors, mining equipment, chemical machinery and irrigation pumps, will be extended.

Birmingham Productivity Exhibition. Against the background of Industry's three-fold task : to sustain the export drive, to meet home needs and to secure our defences, a Productivity Exhibition will be held at the College of Technology, Birmingham, from December 29 to January 6th. It will be opened by the Chancellor of the Exchequer, the Rt. Hon. H. T. N. Gaitskell, C.B.E., M.P. The Exhibition has been organised by the Birmingham and District Advisory Committee of the Midland Regional Board for Industry and produced for them by the Economic Information Unit and the Central Office of Information.

The Third Gauge and Tool Exhibition, organised by the Gauge and Tool Makers' Association, will be held in the New Hall of the Royal Horticultural Society, Elverton Street, Vincent Square, London, S.W.1. from May 15 to May 25th. Gauges and Measuring Equipment ; Jigs, Fixtures and Special Tools ; Special Purpose Machines ; Press Tools ; Portable Power Tools ; Moulds and Dies ; Engineers' Small Tools and Diamond Tools, manufactured by Members of the Association, will be displayed.

" Magnefluid " Clutches, Brakes and Couplings. The U.S. Patent Office has granted to Eaton Manufacturing Company of Cleveland U.S. Patent No. 2,519,449 which relates to a mixture of dry lubricant and powdered iron to be used in magnetically-operated clutches, brakes, and coupling devices. The patent covers any finely divided dry lubricant such as graphite in combination with powdered magnetic material. It is the result of several years' testing and development work, during which time hundreds of mixtures were tried.

Devices containing this dry mixture, when energized by controlled electrical currents, respond accurately, smoothly and almost instantaneously to the increase or decrease of the excitation current. The use of a magnetic-lubricant mixture in a dry state simplifies the problem of sealing the devices against leakage and practically eliminates viscous drag. In most applications the original factory filling should outlast the equipment in which it is used.

Exhaustive life tests on clutches, brakes and couplings in which this mixture has been used have developed no wear on the operating surfaces. It has also been determined that the dry mixture is most effective in clutching and braking devices where speed of response is important, when high temperatures are encountered, and where viscous drag cannot be tolerated.

Howard J. Findley, Manager of Research at Eaton and the one responsible for the invention, states : " The United States Government will be licensed under this patent for military purposes on a royalty-free basis as it is on all patents owned or controlled by Eaton Manufacturing Company, for we believe that this invention will be utilized on many military as well as civilian applications."

The Trade name " Magnefluid " will be used by Eaton to identify devices in which this dry lubricant is used. It is understood that the company intends to offer " Magnefluid " clutches, brakes and couplings in a wide range of sizes.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.1)

Housings for Hydraulic Seals. B.S. 1658 : 1950 lays down the basic dimensions for housings intended to accommodate hydraulic seals for use with reciprocating shafts where the friction caused by the seal is not of major importance and the working pressures do not exceed 5,000 lb./sq. in. It does not apply to seals for use on aircraft.

The Standard deals with both long and short housings of the gland box and piston head types in the range of sizes from 3/18 in. to 20 in. inner diameter and ¼ to 21 in. outer diameter and it stresses the desirability of consultation between the designer of the housing and the manufacturer of the seal in order that the correct tolerances may be applied to ensure satisfactory operation of the seal.

In addition to laying down inner and outer diameters it specifies axial lengths, tolerances in axial lengths, lead-on chamfers and fillet radii.

Although no tolerances are laid down for the inner and outer diameters of the housings the standard will perform a very useful function in enabling designers to choose the best basic dimensions to meet their needs and for which the proper seal will be available. The tolerances on diameter have been omitted because the variety of sealing materials and the range of application are such that hard and fast rules could not be made ; hence the emphasis on consultation between design and manufacturer. Price 2/-.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box number advertisements 1s. extra. Instructions together with remittance must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

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BOOKS

Plastics Moulding Engineering. By M. Freund, Dipl.Ing., M.I.Mech.E. 410 pp., 192 figures. Publishers: Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. PRICE: 45/- net.

There is no lack of books, even of good books, on the various aspects of this important but comparatively young industry. It is generally known, however, that the plastics industry is sparsely provided with good technical men who would endeavour to direct the progress of this industry by taking full advantage of the knowledge attainable through careful study of the engineering sciences. Mr. Freund has been engaged in the plastics moulding industry for 24 years, and during much of this time he has gathered a great deal of evidence of the waste and failures which can be avoided and the economies and improvements which can be gained by the application of sound engineering and metallurgical principles to the processes involved in plastics moulding.

The fruits of the author's rich and valuable experience are collected and logically presented in "Plastics Moulding Engineering," a book which deserves to be widely read and studied not only by all students of the subject, but also by executives and engineers engaged in the plastics industry.

Chapter V, dealing with Stresses in Plastics Moulds (Technical Aspects of Multiple-Cavity Tools) and Chapter XI, on Heat in the Plastics Moulding Shop, deserve especially careful study.

The author himself deems it necessary to tender his apologies for his "lack of elegance in style," and quotes the mathematician Leibnitz: "Elegance is a matter for shoemakers and tailors." This lack of attention to language and style, however, is not conducive to a better understanding of the subject matter and we feel sure that improvements in this respect would add to the value of an otherwise very commendable book.

Analysis and Lubrication of Bearings. By Milton C. Shaw and E. Fred Macks. 618 pp. Publishers: McGraw-Hill Book Co., Inc., 330 West 42nd Street, New York 18, N.Y. PRICE: $10.00.

In this book, the authors have made a most successful attempt to present a unified exposition of the many aspects of bearing analysis. They quote A. G. M. Mitchell's statement that "To the machine designer all bearings are of course only necessary evils, contributing nothing to the product or function of the machine; and any virtues they can have are only of a negative order. Their merits consist in absorbing as little power as possible, wearing out as slowly as possible, occupying as little space as possible, and costing as little as possible." The book has been written not only to introduce the advanced engineering student to the subject, but to provide the engineer in industry with much valuable information on the theory of lubrication in one concise volume.

Principles of Aircraft Propulsion Machinery. By Israel Katz. 477 pp. Publishers: Pitman Publishing Corporation, 2 West 45th Street, New York 19 and Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. PRICE: $6.50 or 35/- net.

Welding Design and Processes. By B. R. Hilton. 342 pp., 168 illustrations. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. PRICE: 36/- net.

Modern Welding Technique. By E. T. Gill, B.Sc., F.I.M. and Eric N. Simons. 276 pp., 88 figures. Publishers: Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. PRICE: 21/- net.

Foundry Sand Control. By W. Davies, Ph.D., M.Sc., F.G.S. 212 pp., 135 figures. Publishers: The United Steel Companies Ltd., 17 Westbourne Road, Sheffield 10. PRICE: 30/- net.

Hardenability and Steel Selection. By Walter Crafts and John L. Lamont. 280 pp. Publishers: Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. PRICE: 35/- net.

Body Engineering. Design and Construction of Motor Vehicle Bodywork. By Sydney F. Page. 188 pp., 142 figures. With Constructional Supplement containing a series of tables and constructions for bodywork. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. PRICE: 24/- net.

Transformers. Their Principles and Design for Light Electrical Engineers. By F. C. Connelly, Ph.D., A.M.I.E.E., A.R.C.S., D.I.C. 490 pp., 179 illustrations. Publishers: Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. PRICE: 35/- net.

Phenomena, Atoms and Molecules. An Attempt to interpret phenomena in terms of mechanism or atomic and molecular interactions. By Irving Langmuir. 436 pp., 27 figures. Publishers: Philosophical Library, 15 East 40th Street, New York 16, N.Y. PRICE: $10.00.

Colours and How We See Them. Royal Institution Christmas Lectures 1946-1947. How Colours Are Used. How Colours Are Seen. Illusions and Strange Properties of Colours. By H. Hartridge, F.R.S. 158 pp., 39 figures and 12 colour plates. Publishers: G. Bell & Sons Ltd., York House, Portugal Street, London, W.C.2. PRICE: 15/- net.

Pump Questions and Answers. Covering the Construction, Application, Operation, Installation, Maintenance, and Troubles of Centrifugal, Reciprocating, Regenerative, Rotary, and Vertical Turbine Pumps. By Roy. Carter, Igor J. Karassik and Elliott F. Wright. 346 pp. Publishers: McGraw-Hill Book Co., Inc., New York, and McGraw-Hill Publishing Co. Ltd., Aldwych House, London, W.C.2. PRICE: $5.00 or 42/6 net.

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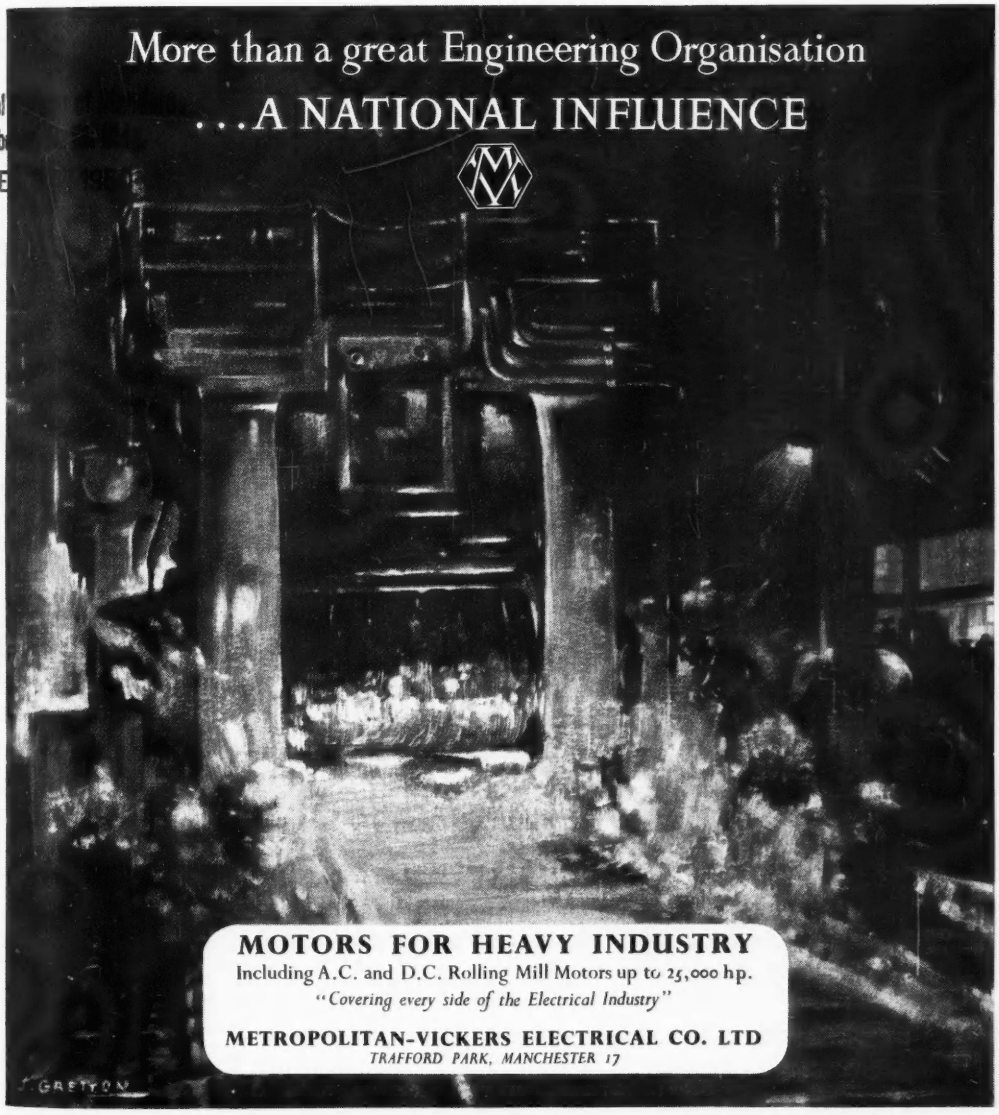
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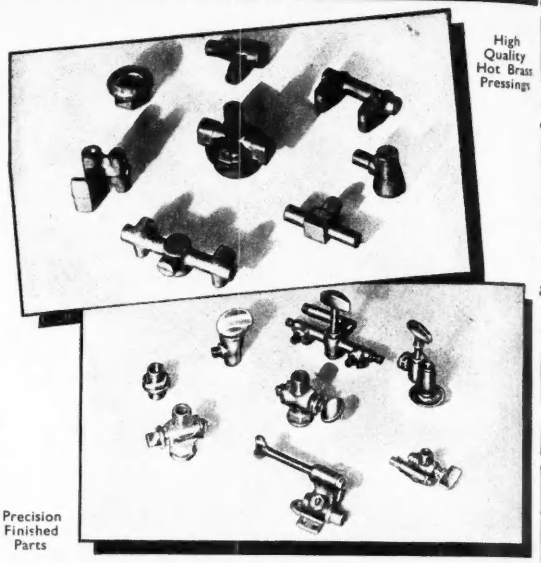

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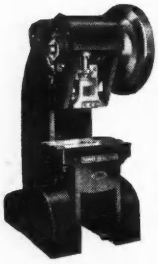

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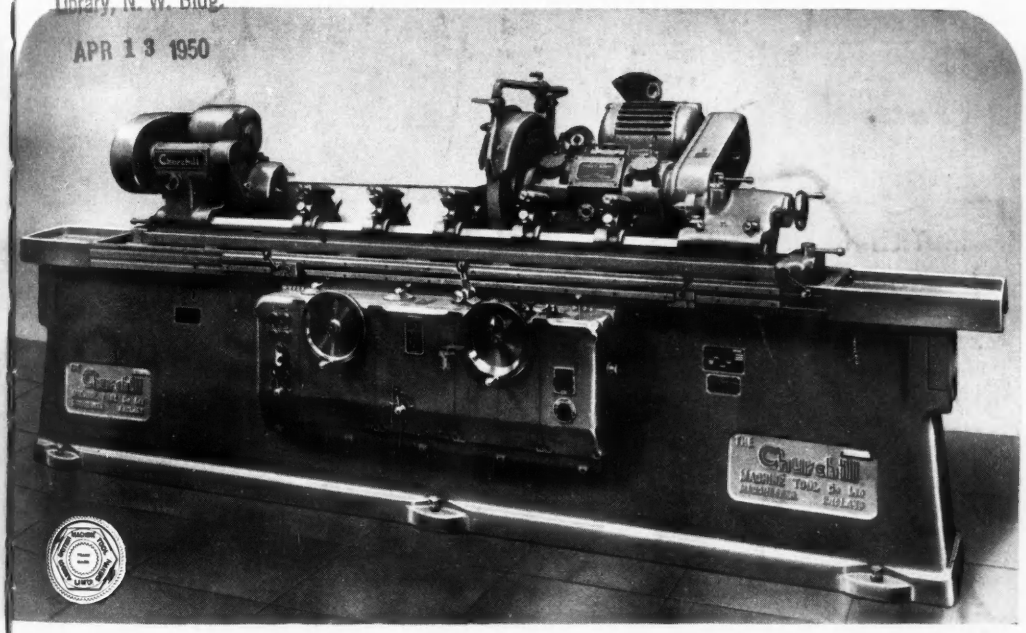

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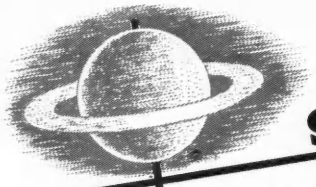

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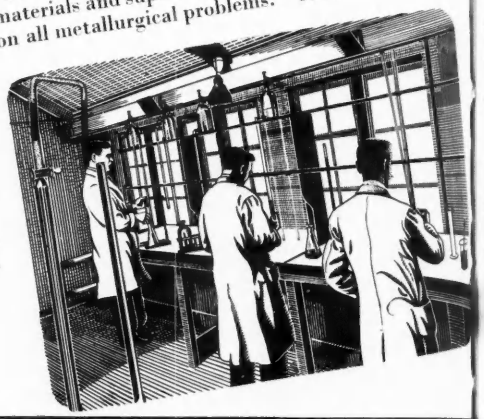

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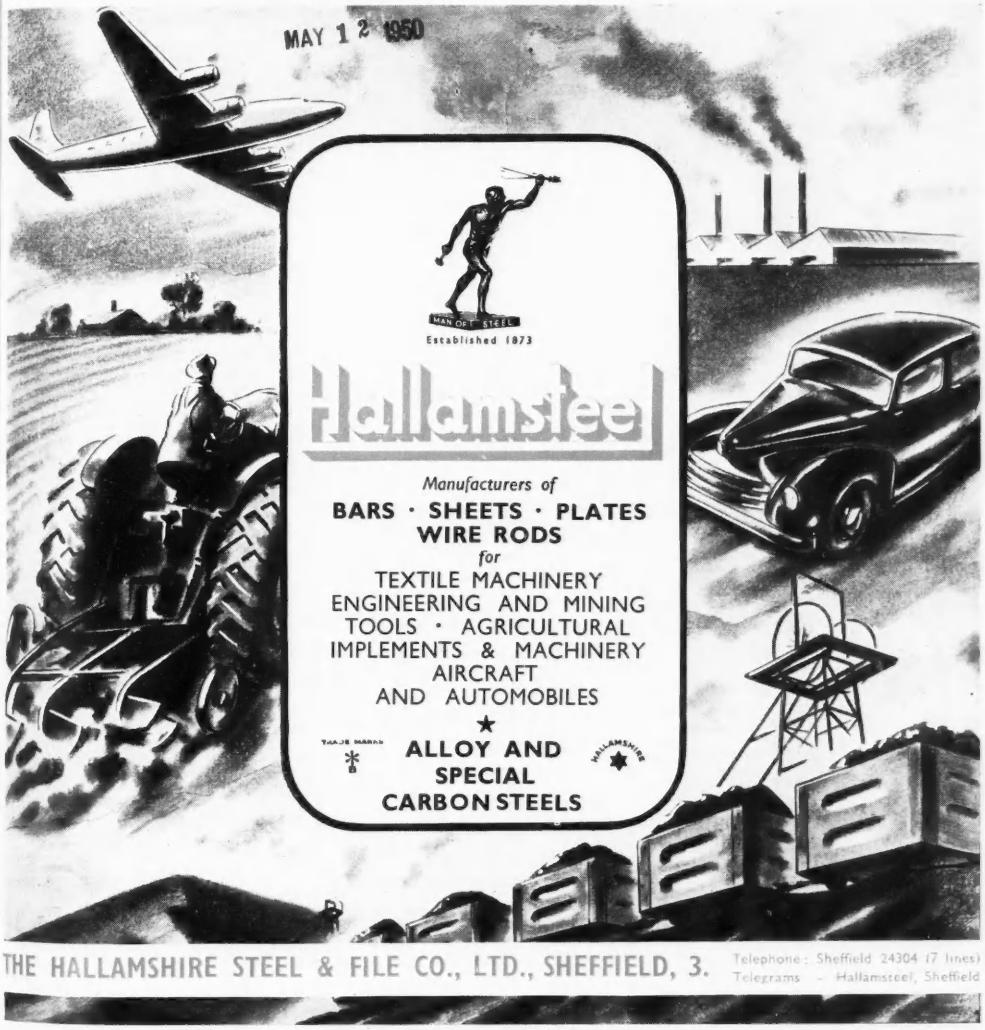

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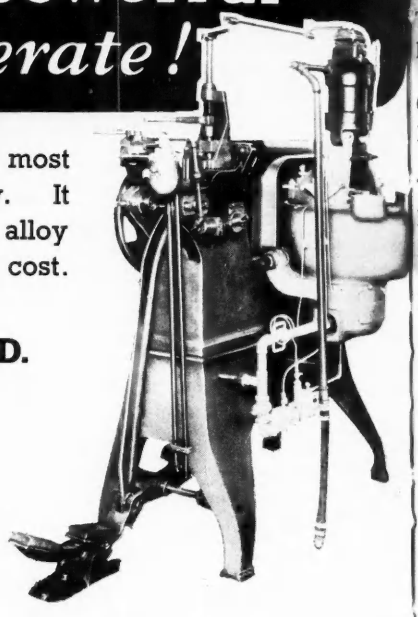

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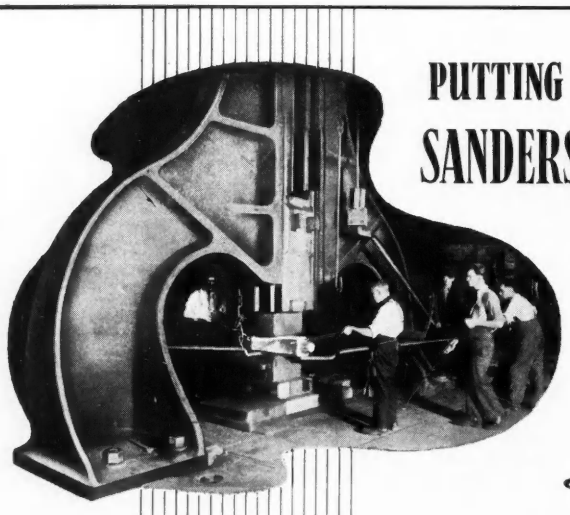

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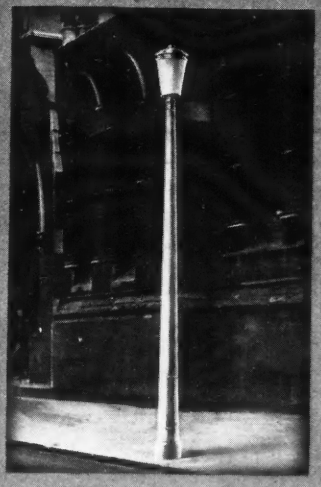

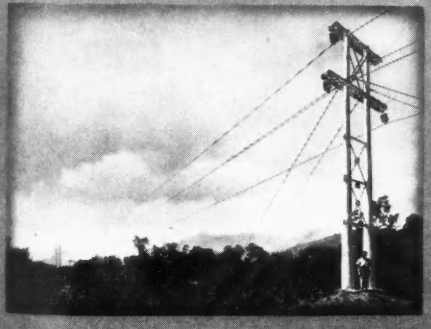

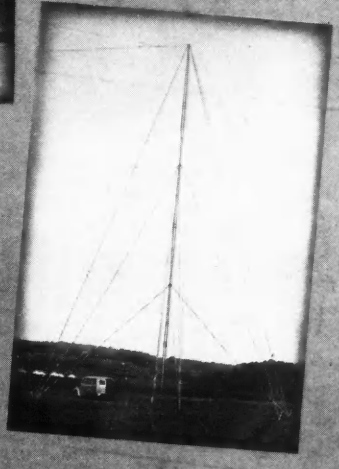

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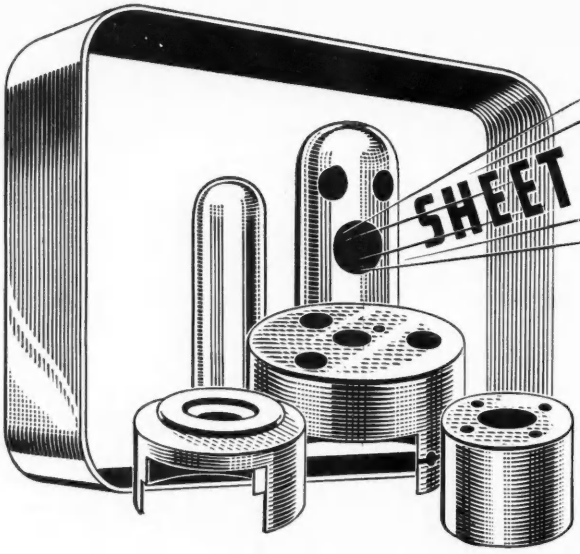

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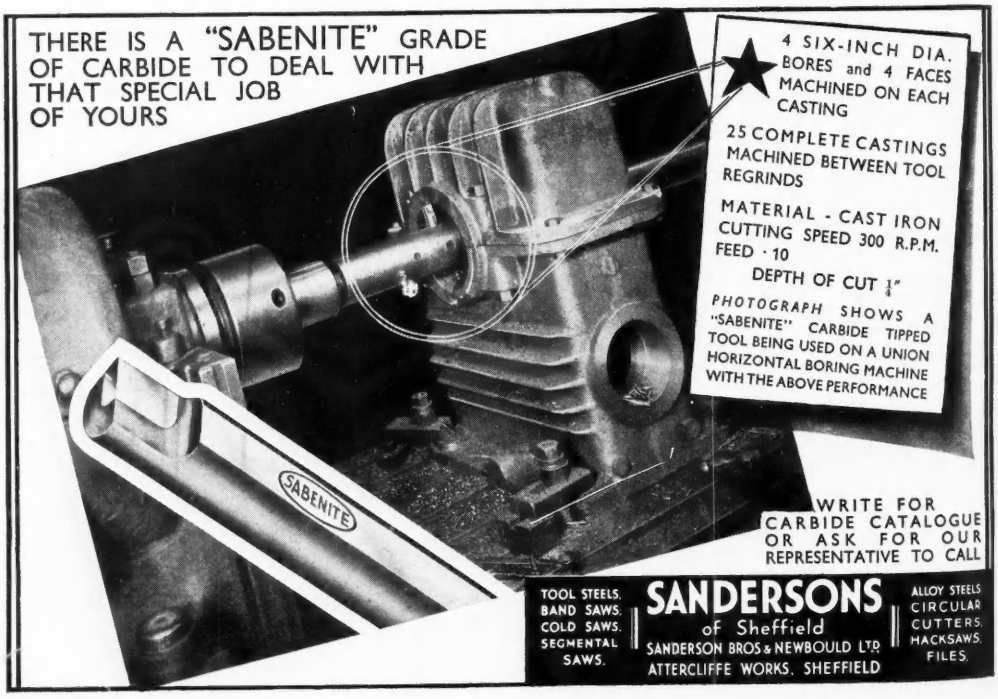

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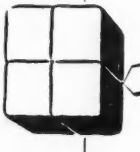

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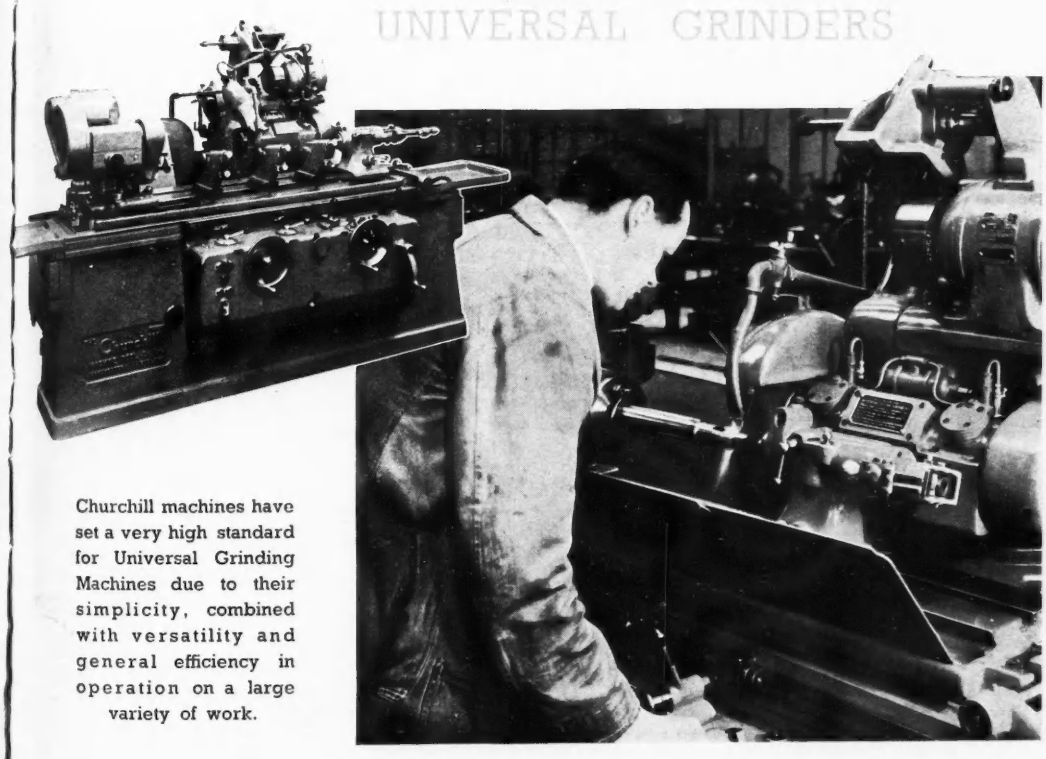

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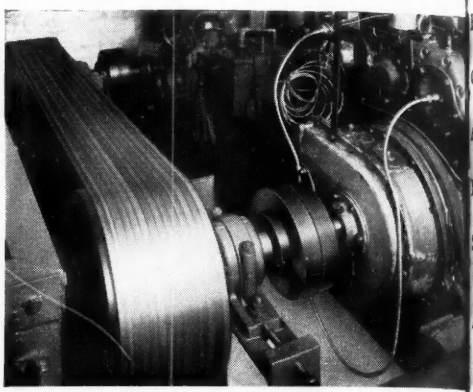

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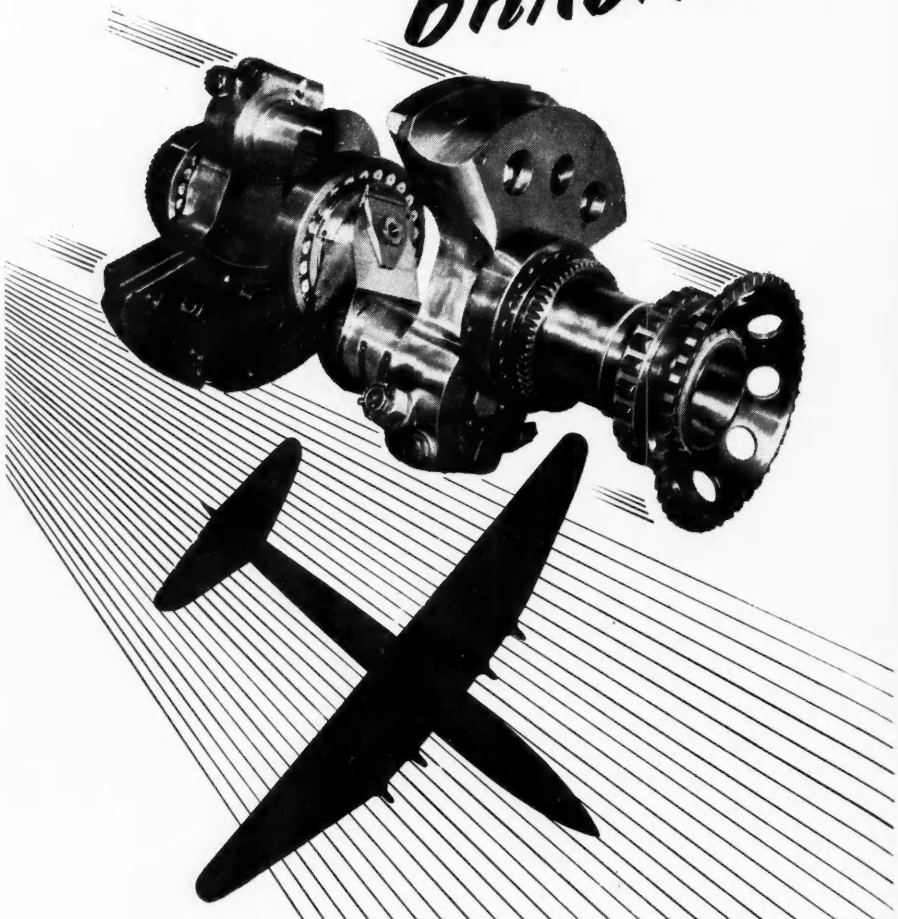

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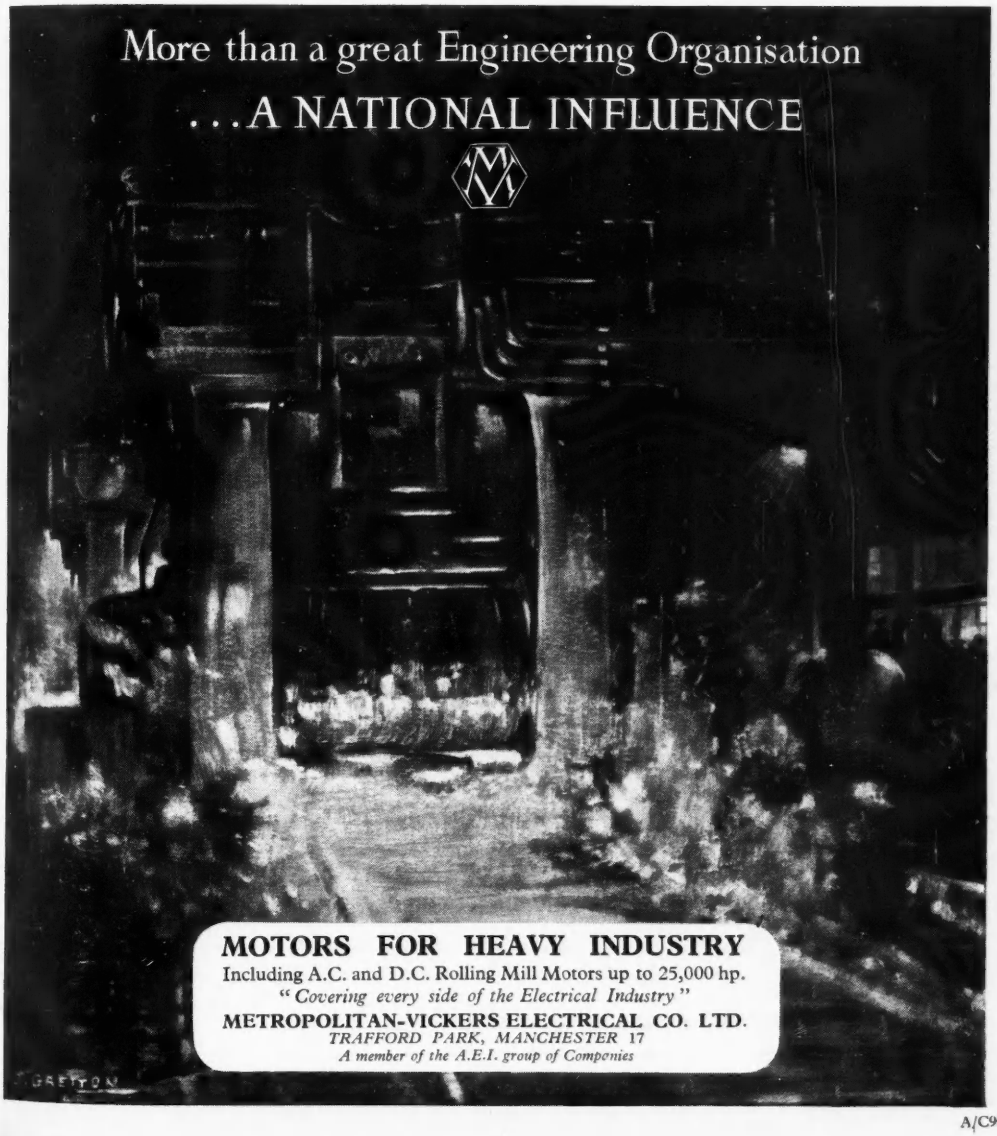
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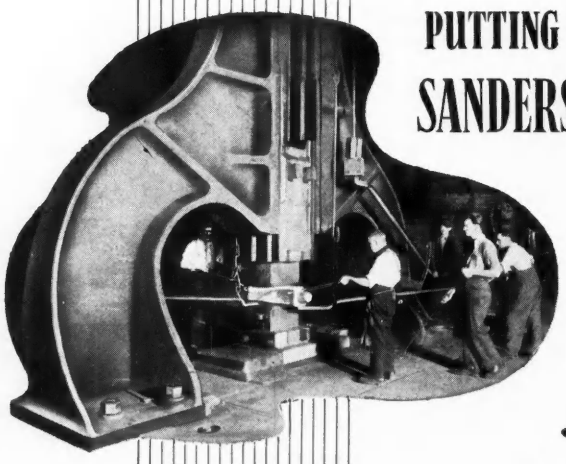

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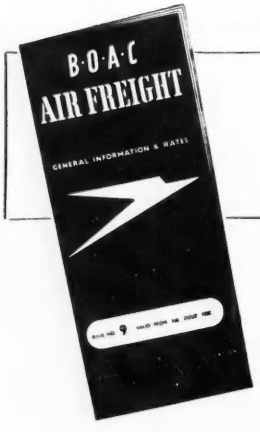

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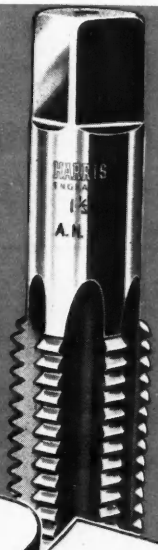

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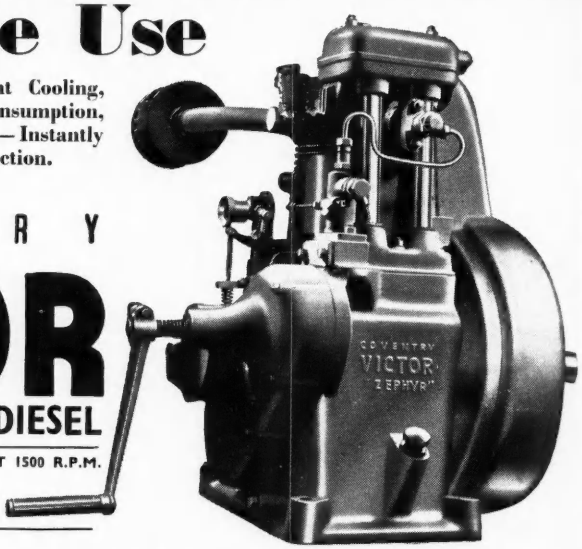

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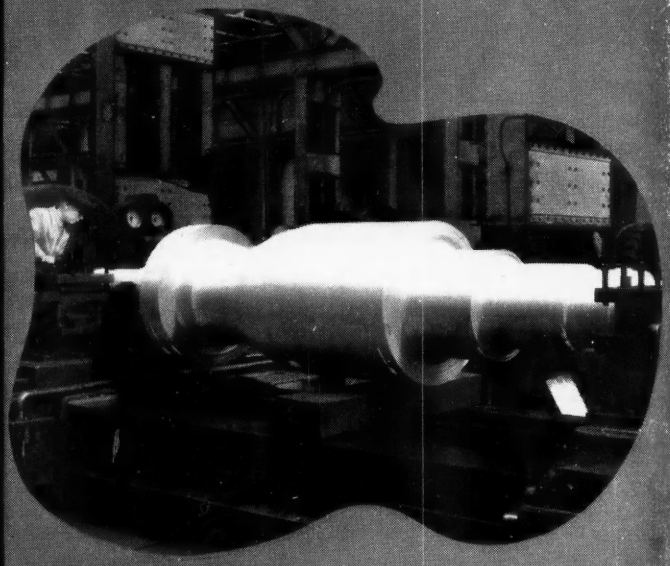

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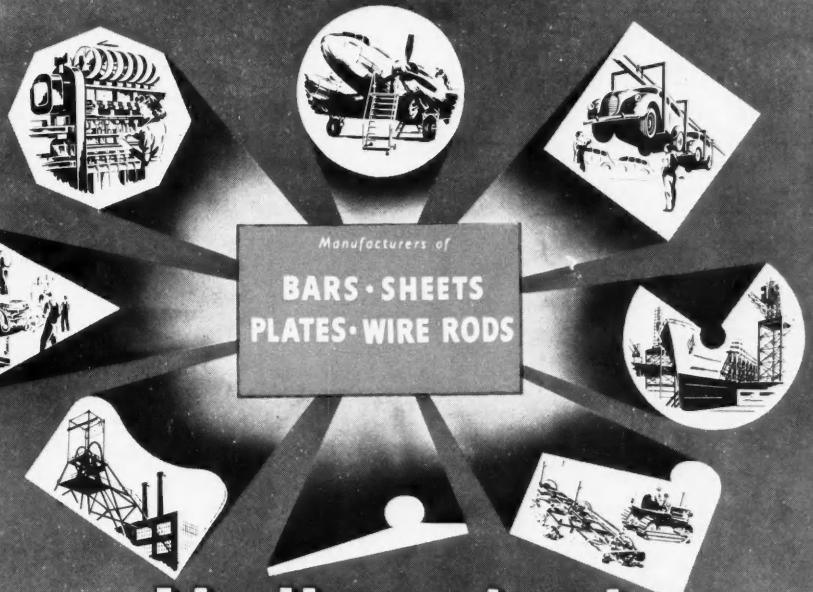

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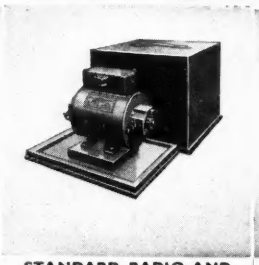

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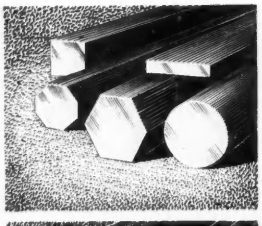

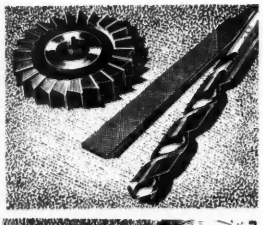

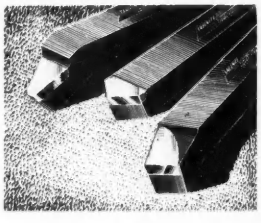

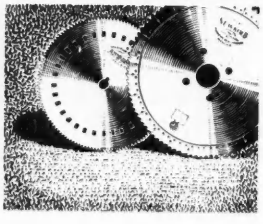

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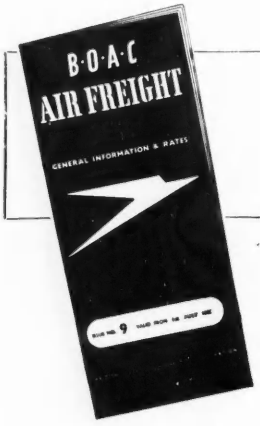

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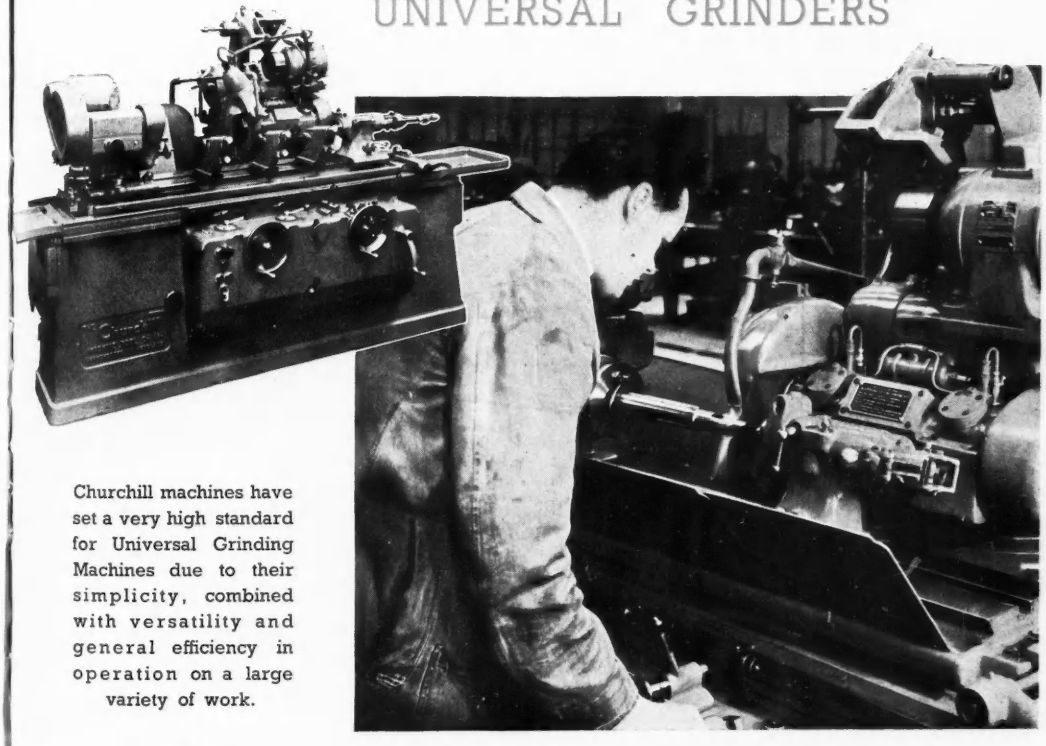

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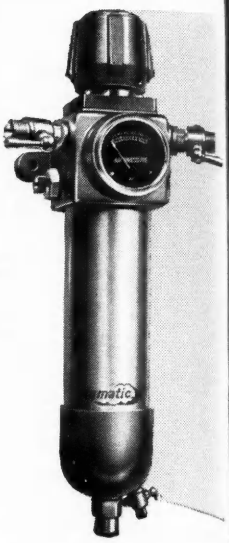

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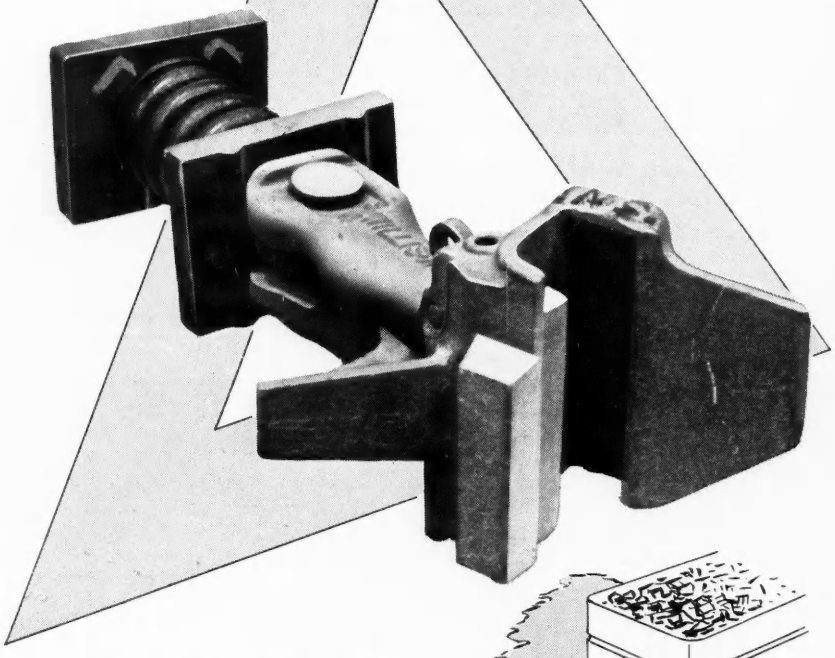

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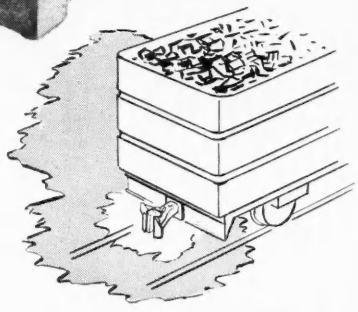

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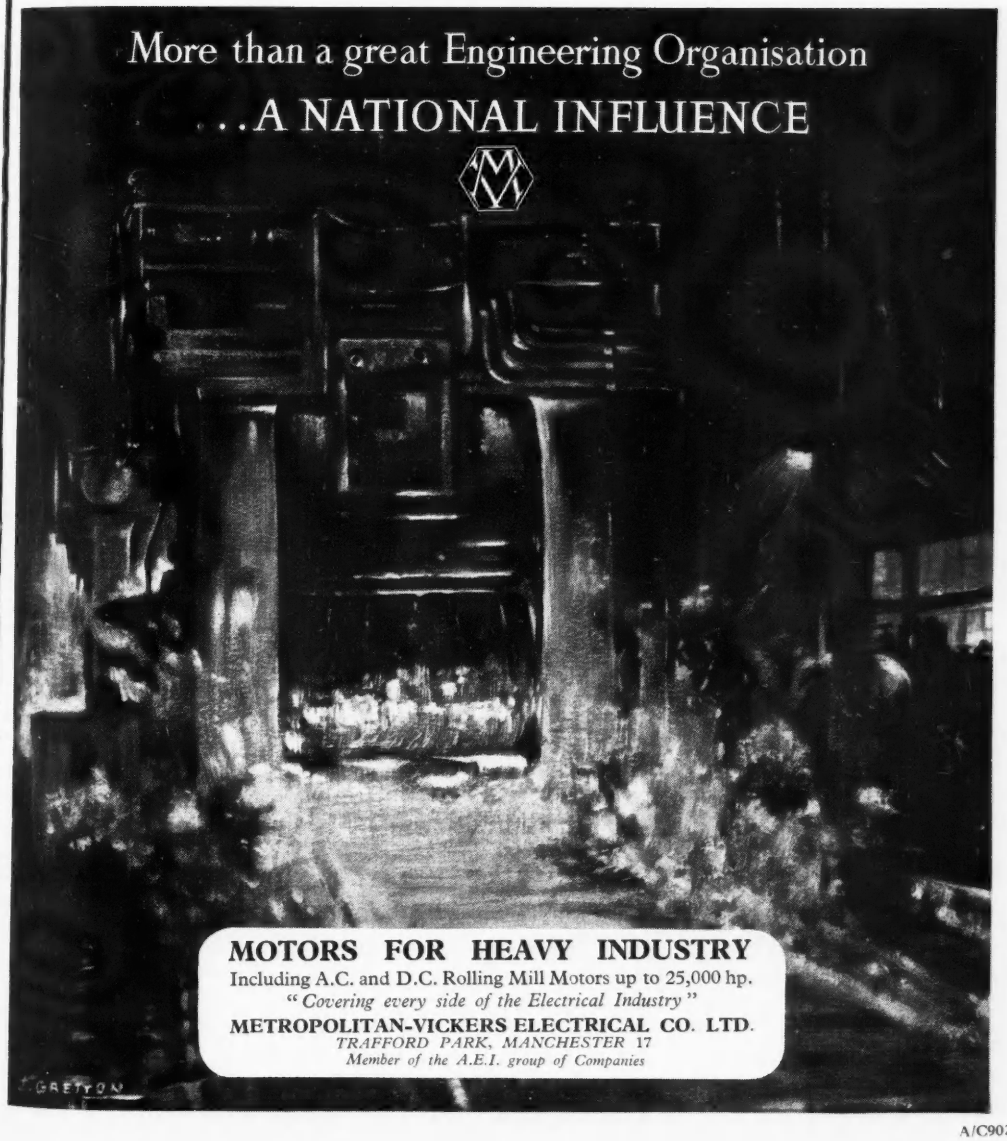
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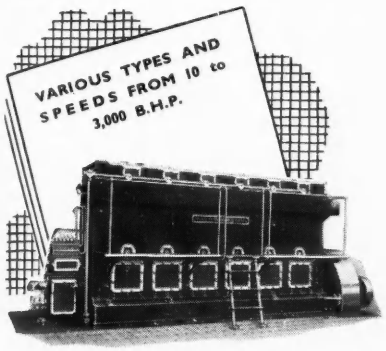

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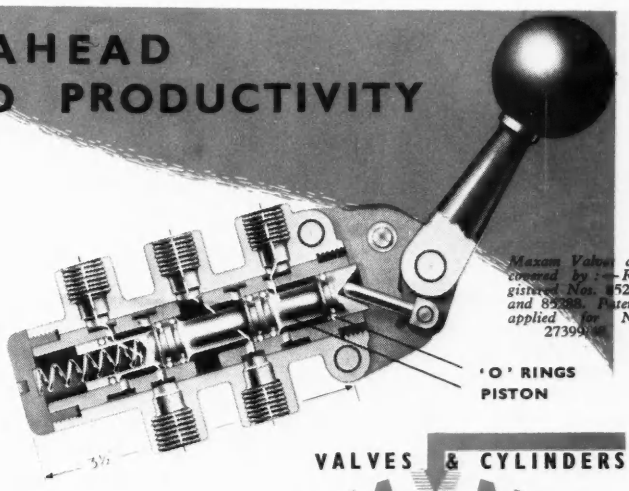

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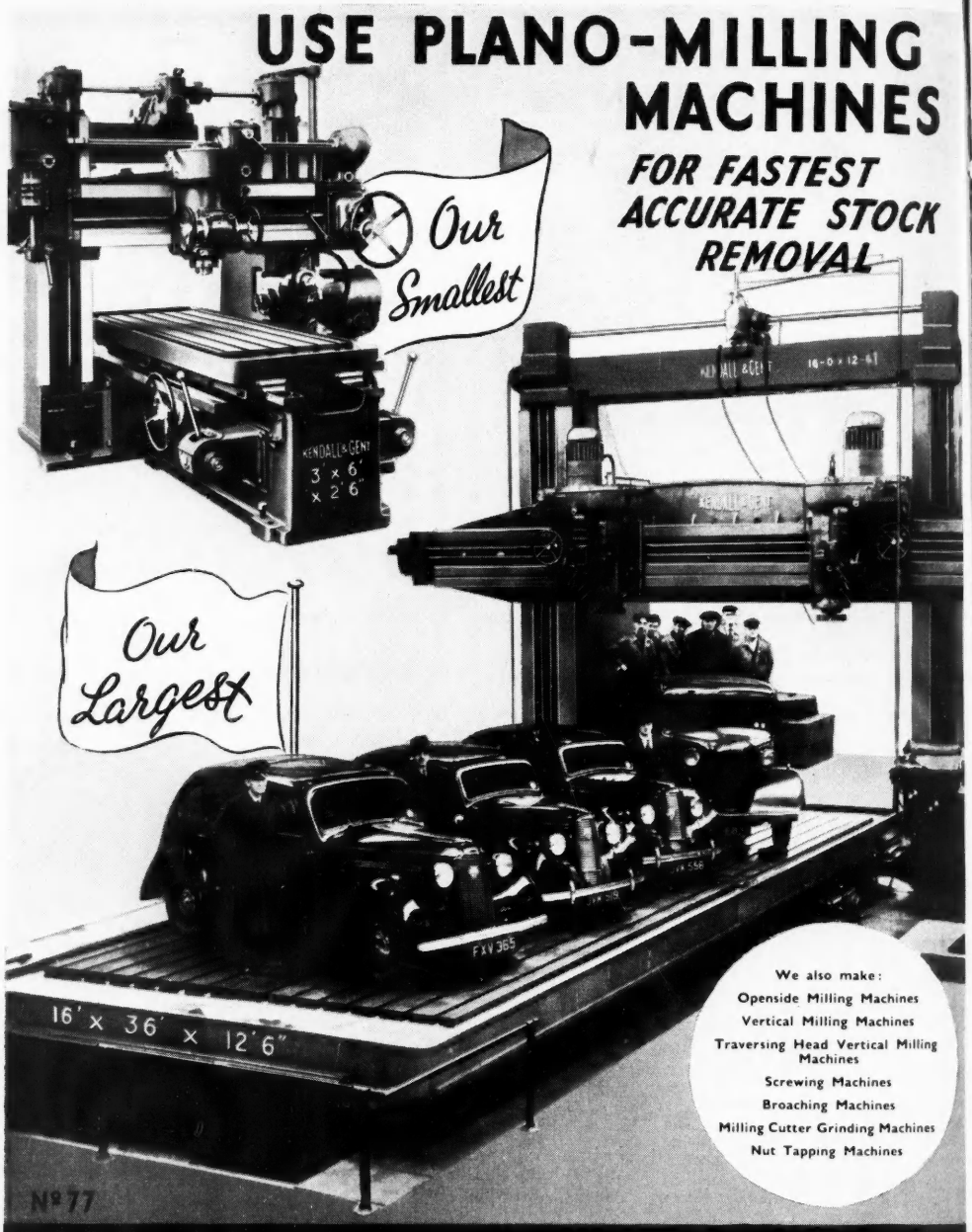

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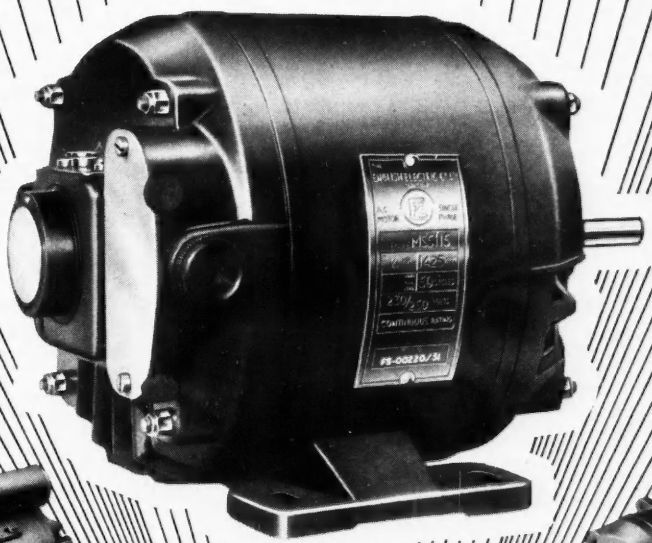

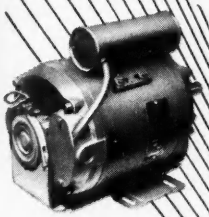

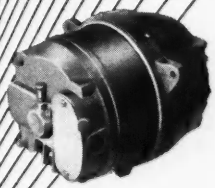

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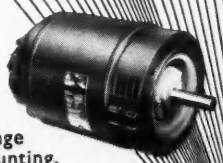

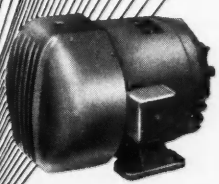

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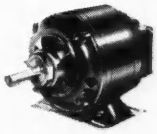

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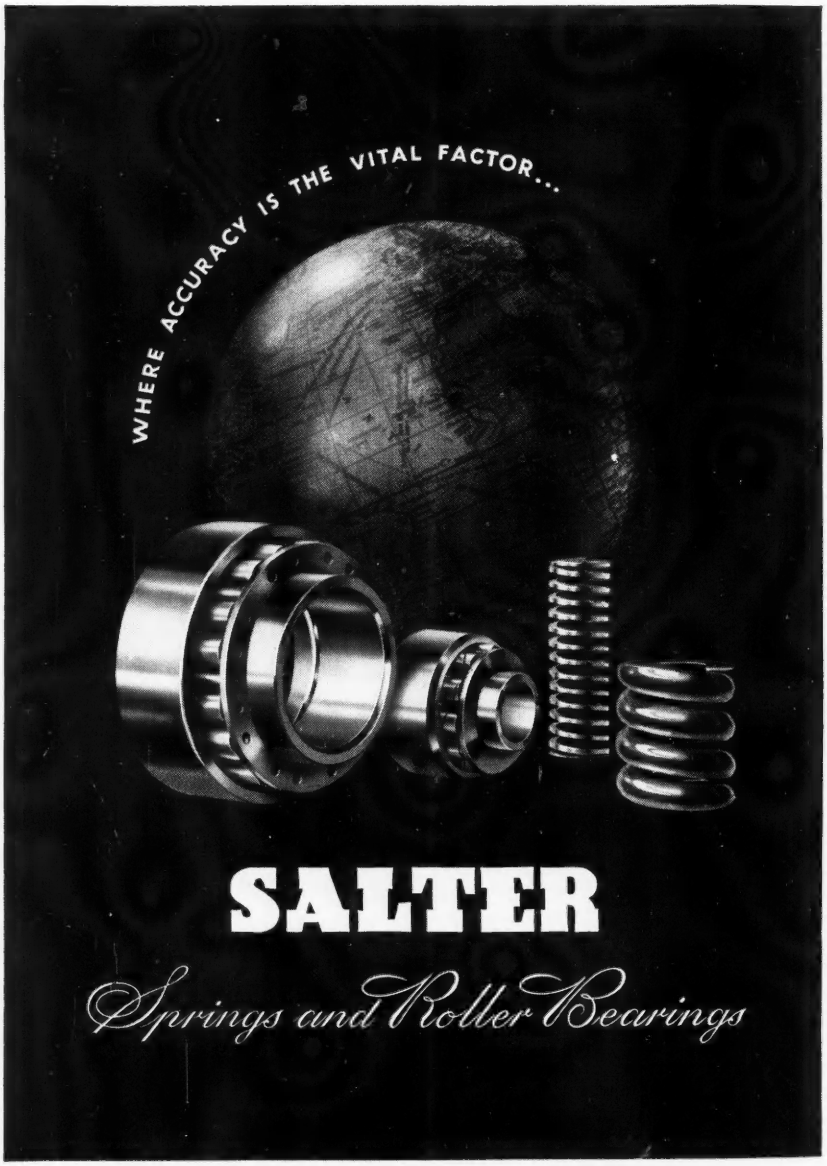

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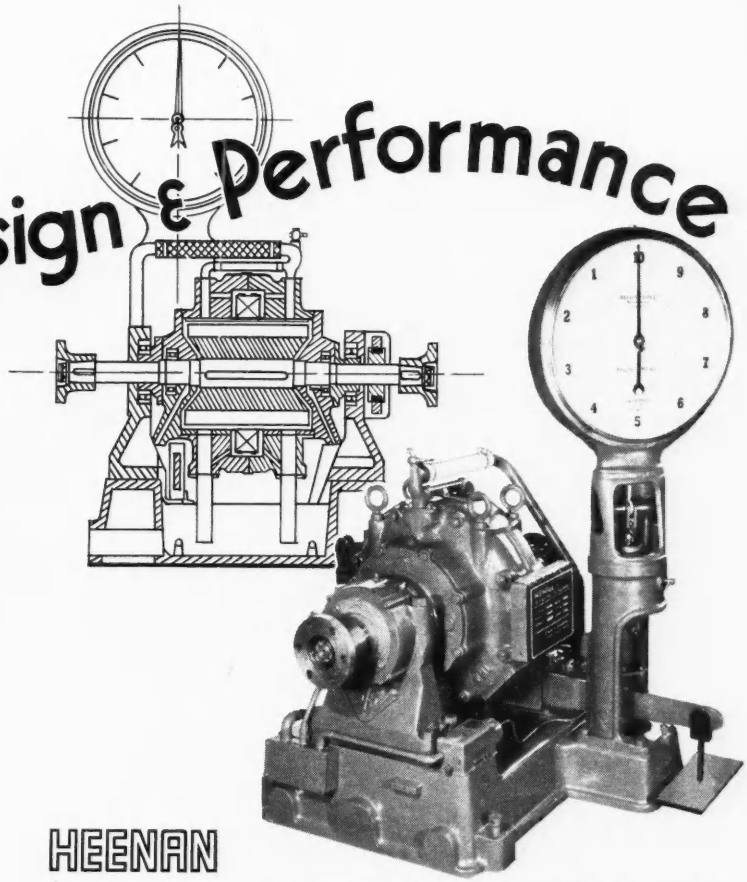

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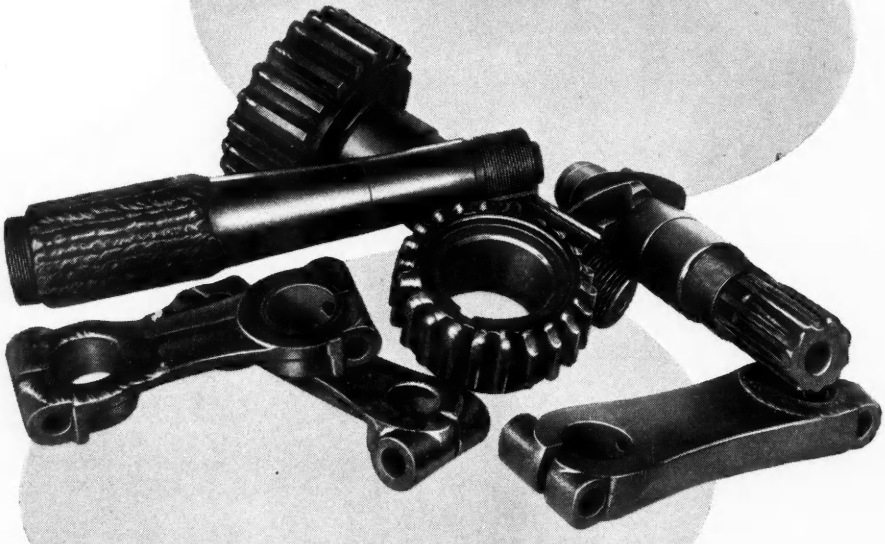

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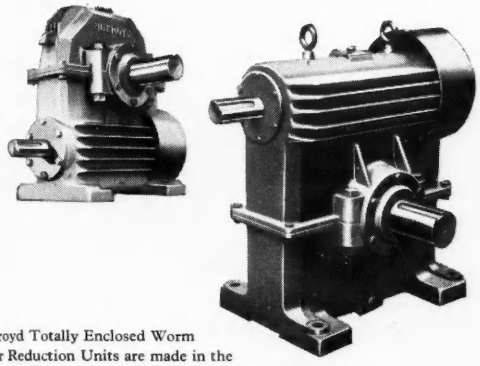

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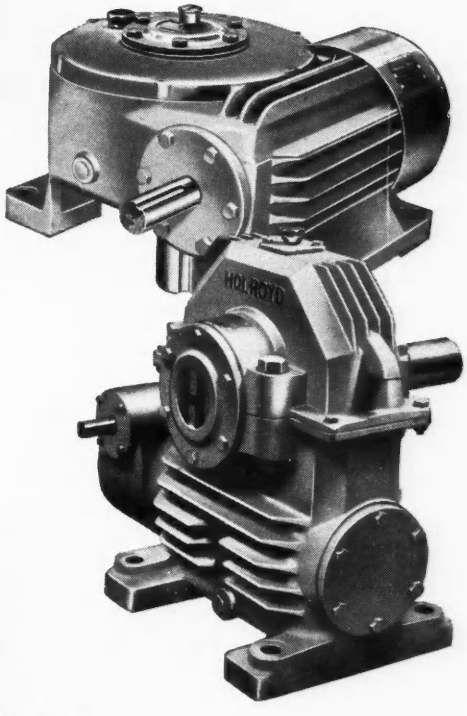

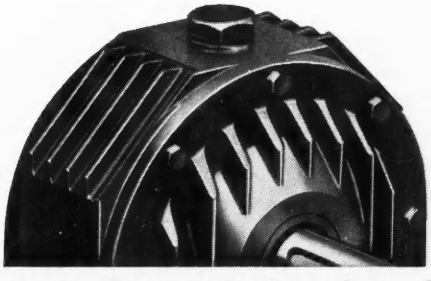

Holroyd Gear Reduction Units JOHN HOLROYD & CO. LTD., MILNROW, LANCASHIRE
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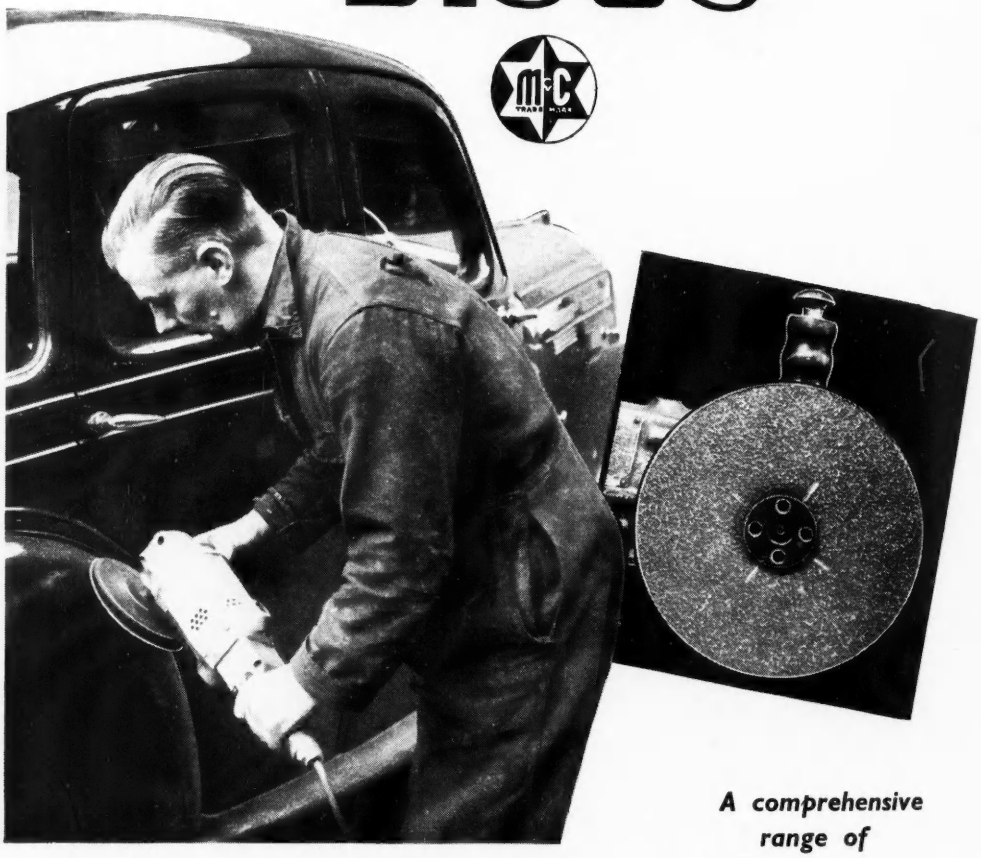
SANDING DISCS



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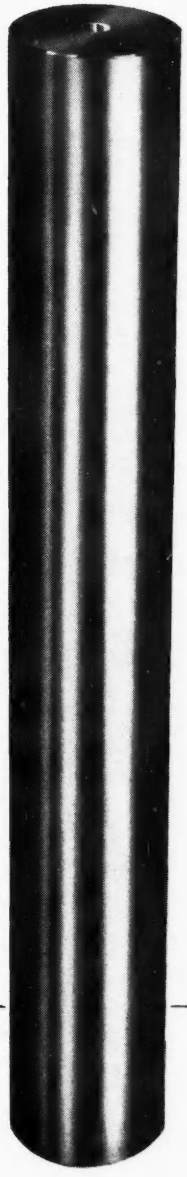

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Those who make bronze bushes from 'as cast' material may find it worth while to consider our new range of machined bronze bars.

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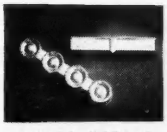

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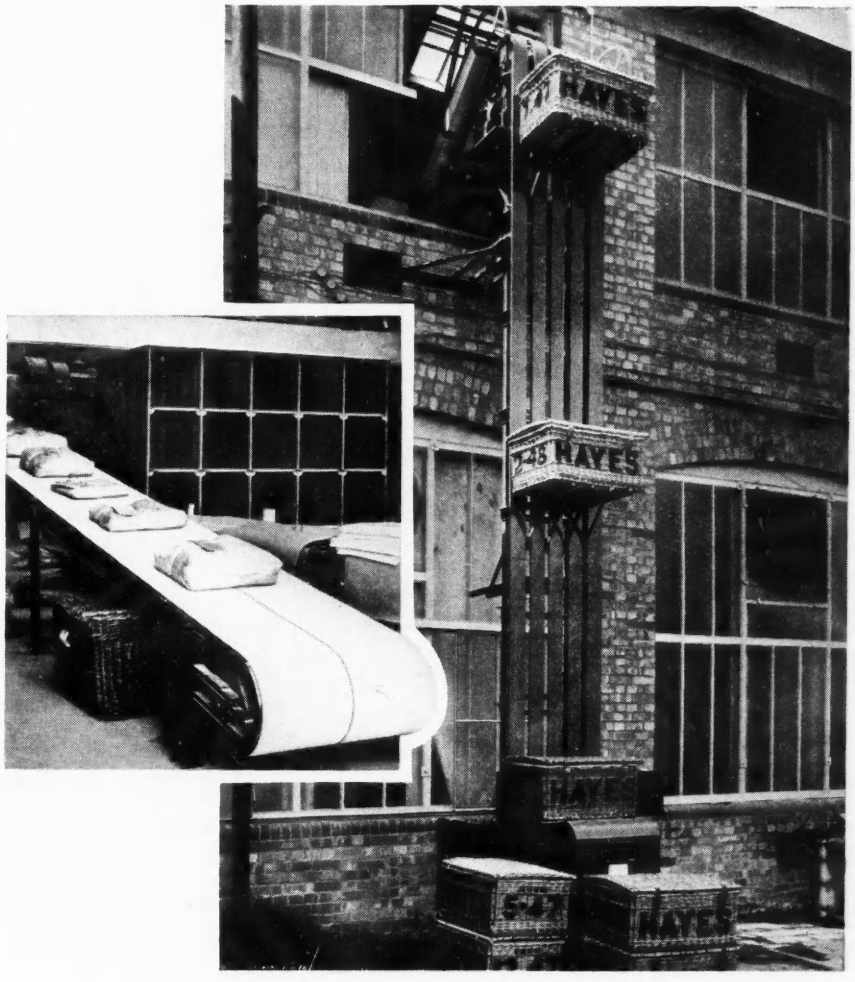

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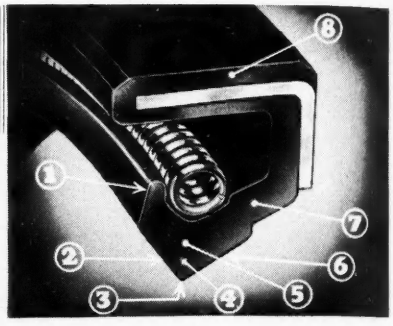

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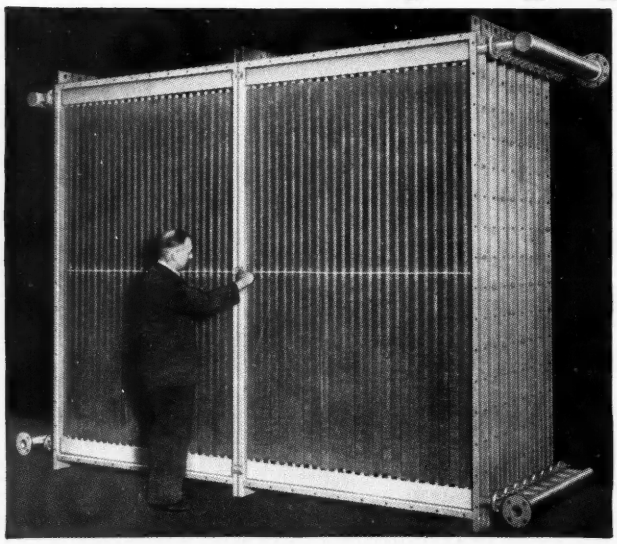
WELDEX HEATERS

INFORMATION ON PLANNED HEATING AND VENTILATING

Process Heating & Cooling Equipment



"Weldex" Air Heaters have unlimited application to the many different drying processes employed in modern industry. Machines for drying textiles, china clay, milk bottles, etc., incorporate specially designed "Weldex" heating elements, while complete batteries similar in constructional detail to the well known "Weldex" Plenum Air Heaters are called for in the bigger type of plant where large volumes of air at high temperatures are used as in paper manufacture, timber kilning, etc.

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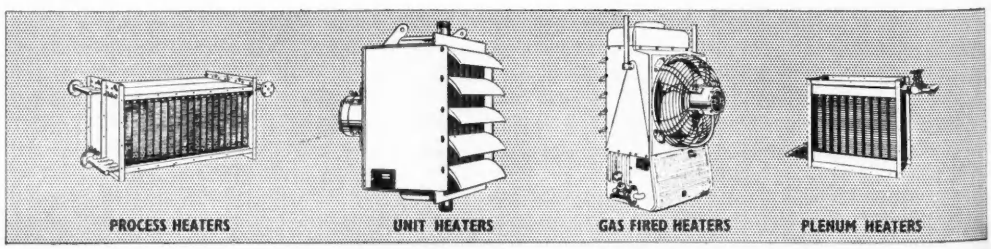

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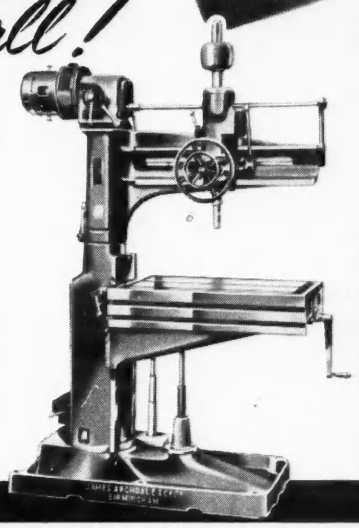

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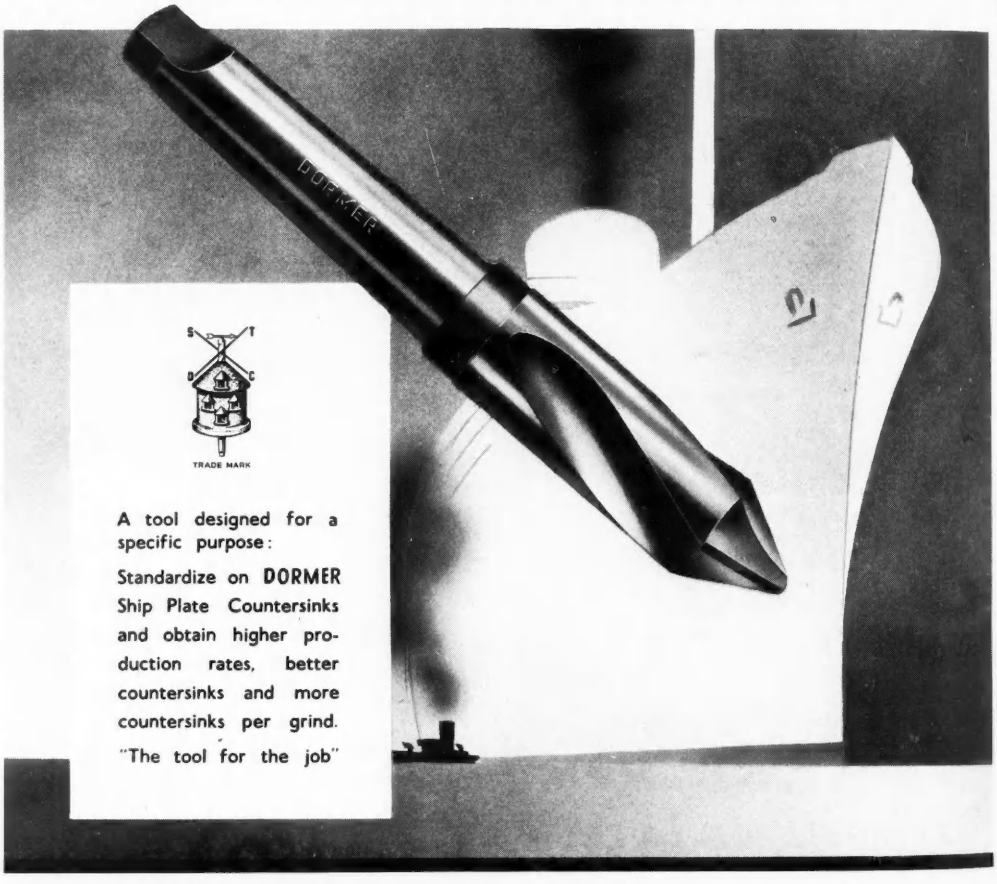
DORMER SHIP PLATE *COUNTERSINKS*



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Standardize on **DORMER** Ship Plate Countersinks and obtain higher production rates, better countersinks and more countersinks per grind.

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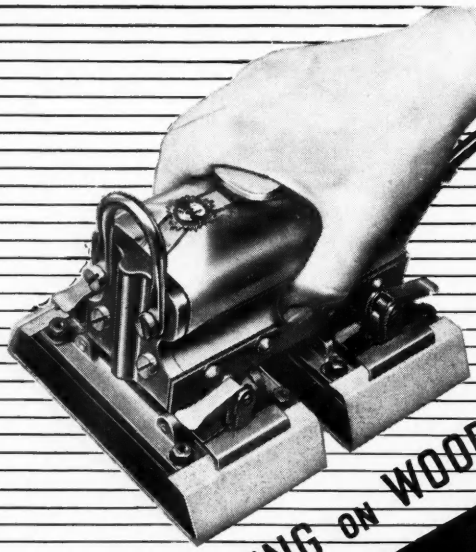

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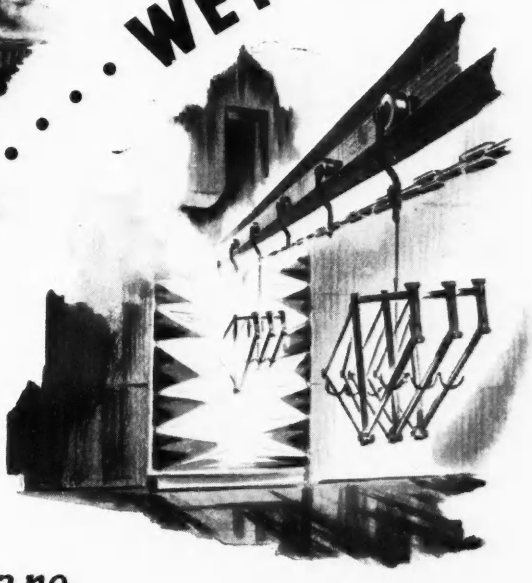

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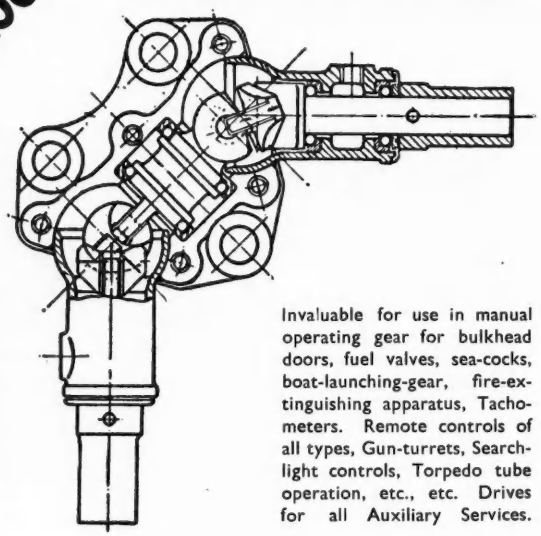

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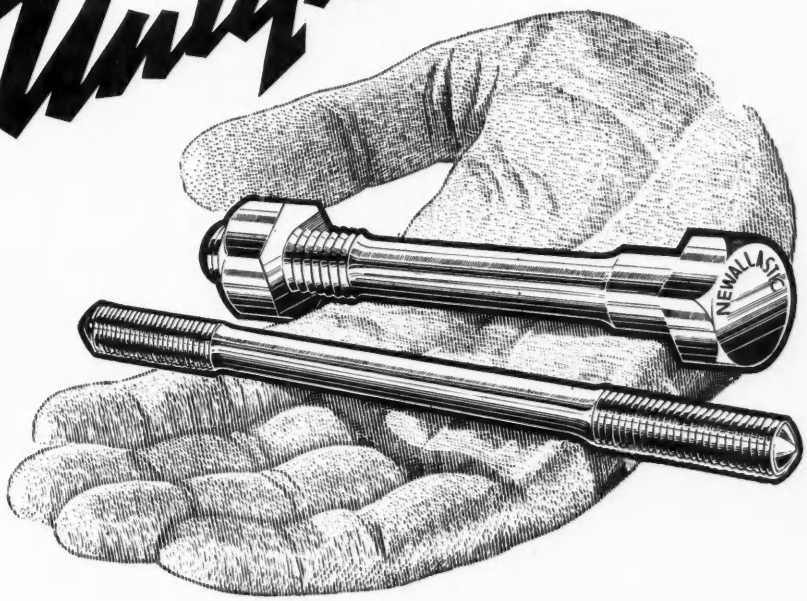

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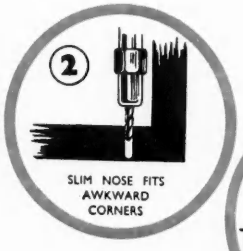

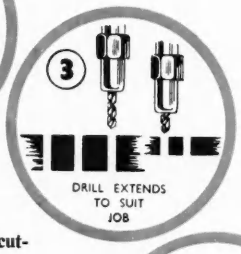

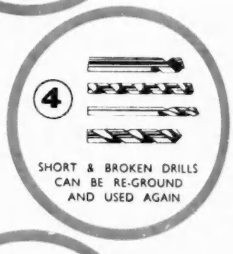

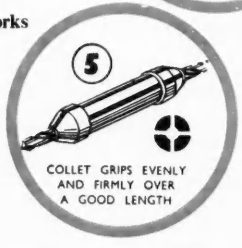

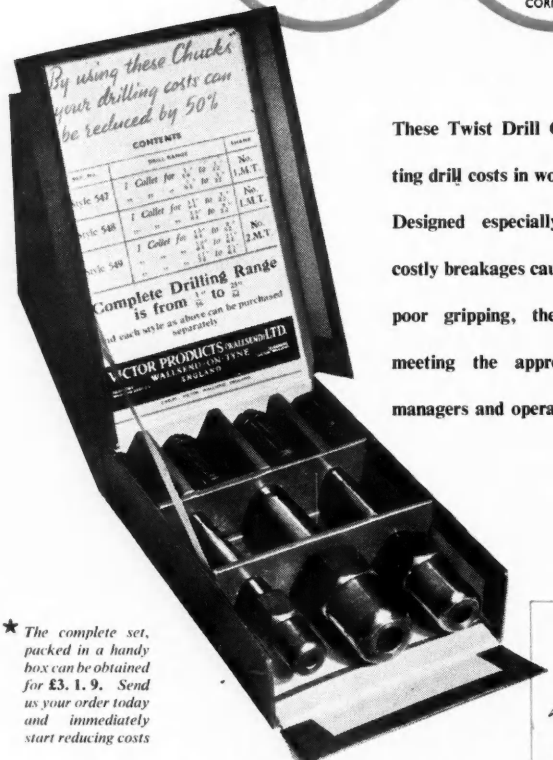
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REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XI. No. 12 DECEMBER, 1950

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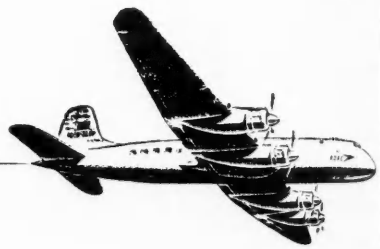

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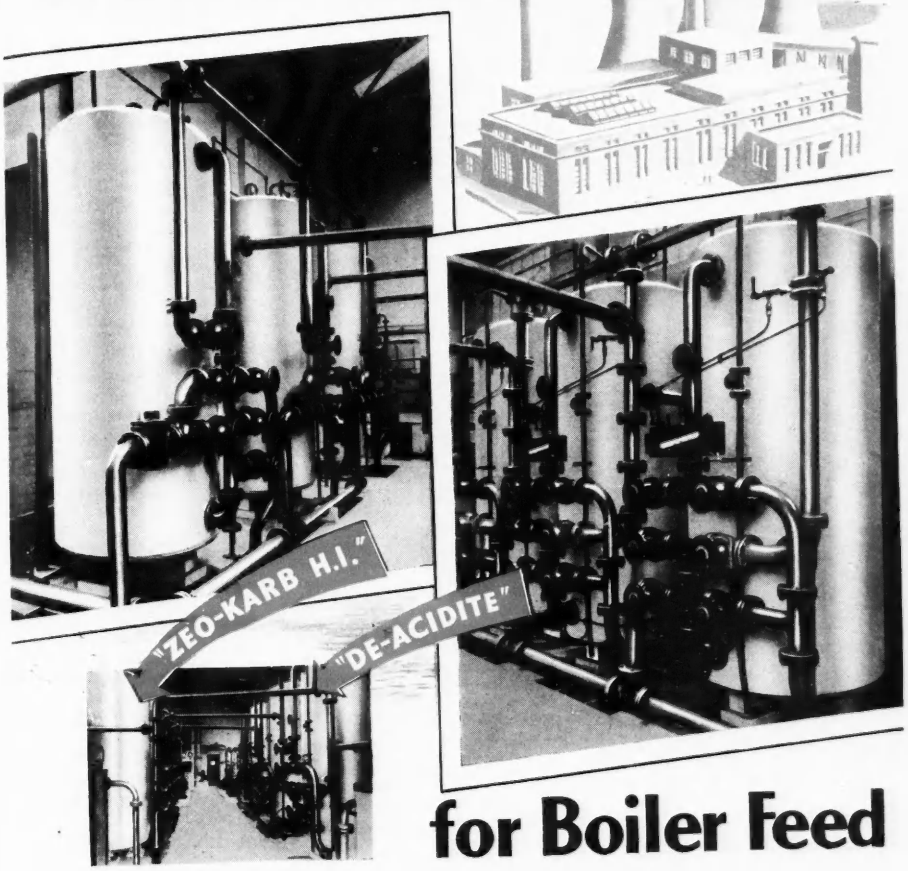

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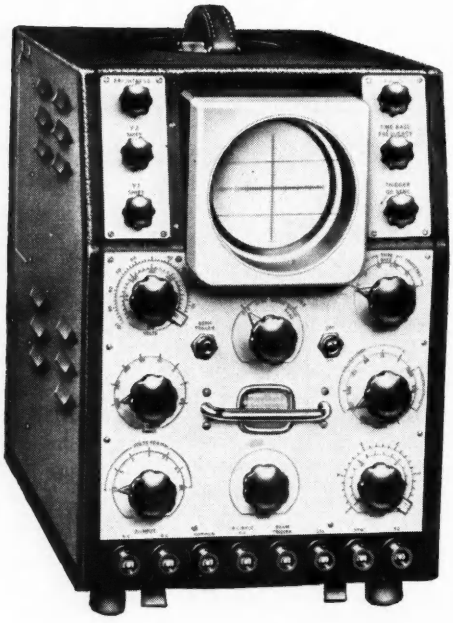

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CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

ILLUMINATING ENGINEERING

Controlling the Luminous Intensity of Fluorescent Lamps by means of Relay Valves.

By K. W. HESS and F. H. DE JONG. (From *Philips Technical Review, Holland*, Vol. 12, No. 3, September, 1950, pp. 83-93, 15 illustrations.)

THE usual methods for controlling the luminous intensity of incandescent lamps, for instance, by means of a variable-ratio transformer or a series resistor, do not lend themselves for application to tubular lamps or other gas-discharge lamps. A good control device for such lamps (on a.c. mains) consists of a pair of relay valves connected in anti-parallel, the ignition point of which can be varied, for instance, by means of a phase-shifted grid voltage. A perfectly gradual variation of the luminous intensity of fluorescent lamps between the maximum and a very low value (70 to 100:1) is possible when the conducting strip provided on modern lamps is earthed. To keep the cathodes of the lamps at the right temperature, it is necessary that they be heated with a filament current as long as there is no discharge current. For this purpose, separate transformers are needed; on the other hand, starters can be dispensed with. With this method of control, which lends itself well to remote control, tubular lamps can be used also in theatres, cinemas and lecture halls, and for stage lighting and other purposes where the luminous intensity has to be gradually lowered or increased. The same applies to high-tension fluorescent lamps. A demonstration apparatus serving 35 tubular lamps of 40 W is described. Here, the alternating grid voltage is peak-shaped; it is derived from a special transformer and can be shifted in phase by means of a small variable resistor. Some particulars are given of the relay valves employed.

INSULATING MATERIALS.

Ionization Processes in Solid Insulators

By B. HELLER and J. VEVERKA. (From *Elektrotechnicky Obzor, Czechoslovakia*, Vol. 39, No. 13, 1950, pp. 229-234, 18 illustrations.)

SOLID insulators and also the oil-filled paper insulation of cables contain gas-filled spaces, which spark over if a sufficiently high voltage is applied. There is usually one spark-over on each half-cycle, when the voltage is alternating. It is possible, however, that several sparks may occur in a half-cycle in the following manner: The gas-filled space sparks over first after the beginning of a half-cycle. The charged conducting particles of the spark flow very rapidly to opposing faces of the space, where they remain, thus constituting a space charge. The space charge quenches the spark current. The voltage of the first half-cycle increases further and reaches a value at which the gas-filled space sparks over again in spite of the space charge created by the first spark. The second spark increases the space charge. By a further increase of voltage, a third spark is caused, and so on.

The insulator with the gas-filled space can be represented by the model shown in Fig. 1, C_1 being the capacitance of the insulator, and C_2 that of the gas-filled space. The gas-filled space is represented by C_2 in parallel with a sphere gap and a resistance. The authors derive the differential equation of this model circuit and give solutions for various circuit parameters. The results

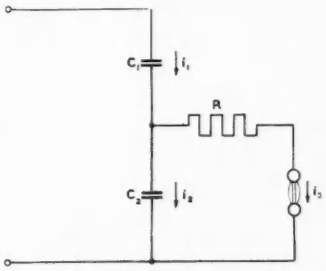

Fig. 1

compare favourably with oscillograms taken on an experimental model circuit. The dependence of the loss angle of the insulation upon the applied voltage is also derived.

MACHINE SHOP PRACTICE

Bending and Twisting Carbide Tools

By D. KAUFFMAN. (From *The Tool Engineer, U.S.A.*, Vol. 25, No. 4, October, pp. 24-26, 12 illustrations.)

THE art of bending carbide is no stranger to today's progressive tool fabricators. Wear parts, cutting tools and gauges lend themselves to economies of time and money with bent carbides. Many costly performed pieces of carbide can be duplicated in a few minutes. Where large pieces are required, several small pieces can be bent and assembled by piecing together to match a large one. The resulting gaps rarely cause harm, even in cutting tools.

This article does not intend to point out that bending can replace pre-forming. It is useful only for those applications where other methods are unsuitable. When torch heating, the heat should be applied with a large tip, and as quickly as practical. A flame with a maximum of oxygen should be used and held close to the carbide. It is necessary to watch the carbide carefully so as not to use excessive heat as this will over-oxidise the surface or melt it. The "sparkling" that ensues when overheating takes place is very damaging and destroys the carbide. The carbide should be heated until it is at white heat just below the sparkle stage and bent with a minimum of pressure. Excessive pressure will cause the carbide to crack open on the outer sides and also become too porous. To date the writer had found no damage to bent carbides when reasonable caution was exercised.

Power Brushing Deburrs Gears

By R. O. PETERSON. (From *Steel, U.S.A.*, Vol. 127, No. 15, October 9, 1950, pp. 80-81, 3 illustrations.)

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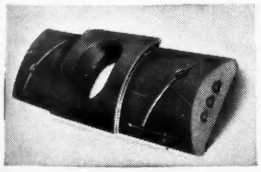

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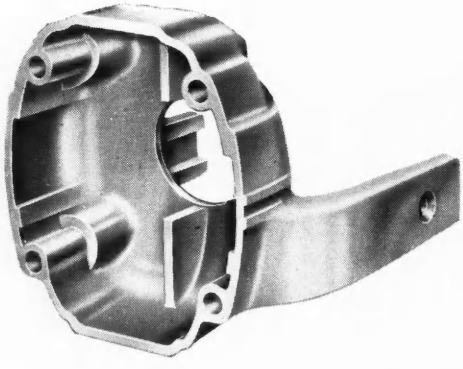

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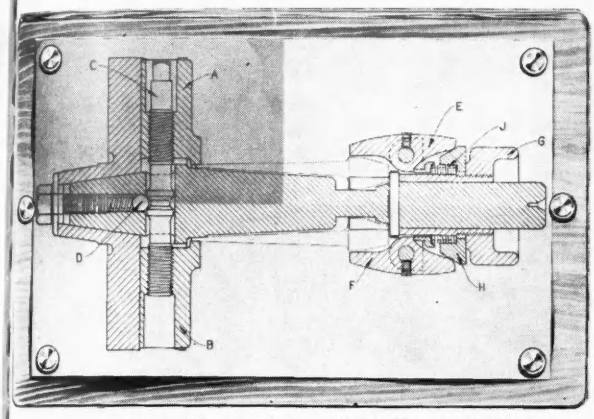

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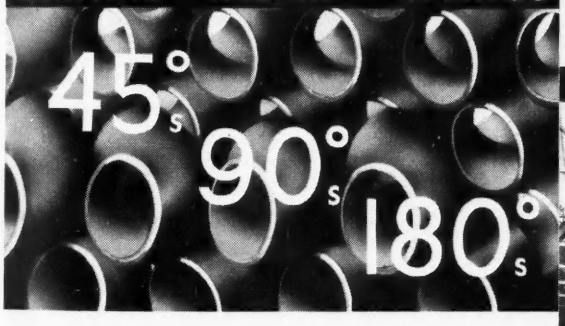

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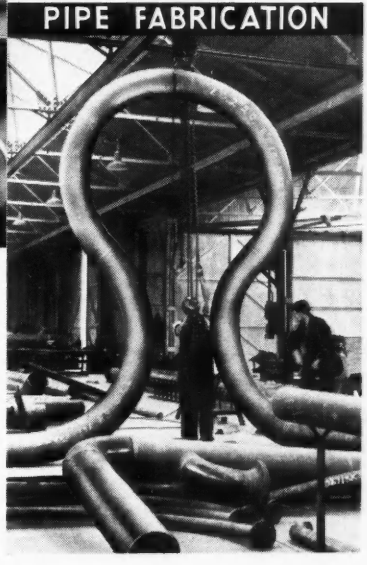

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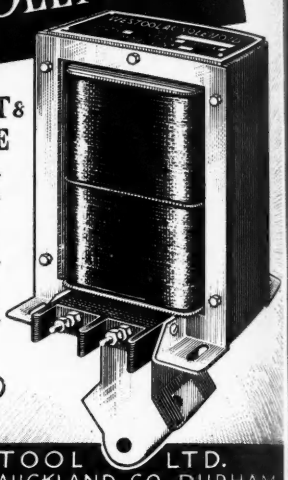

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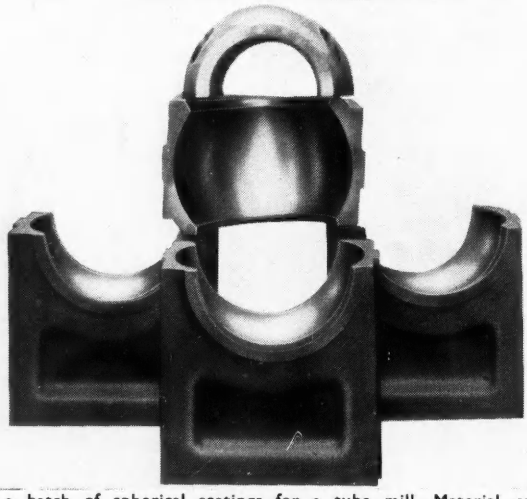

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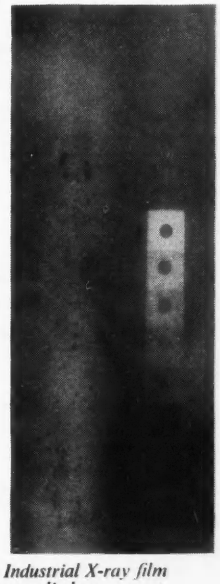

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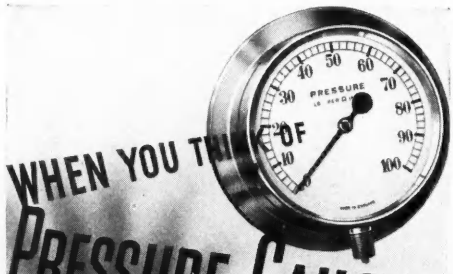

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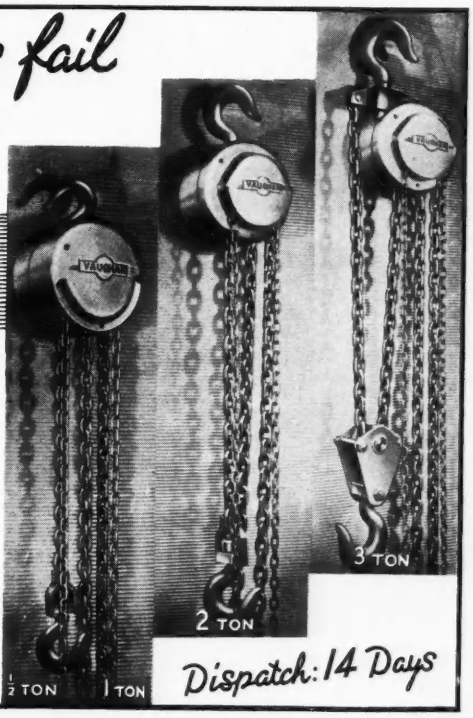

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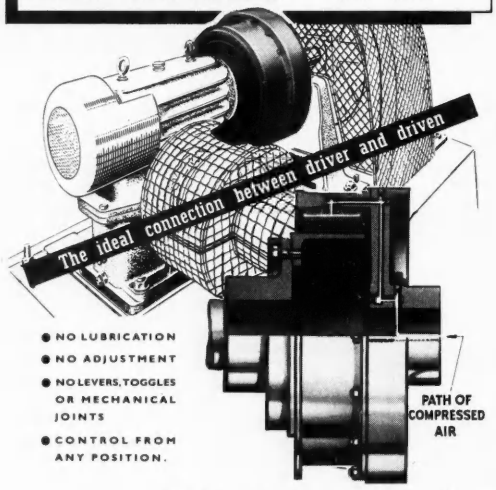

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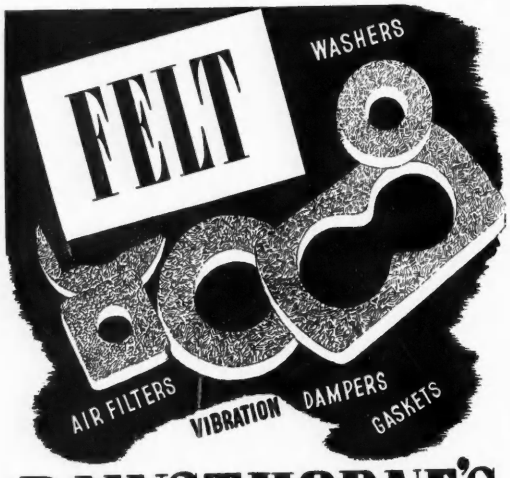

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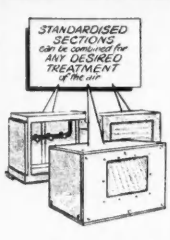

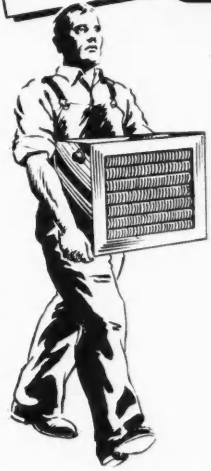

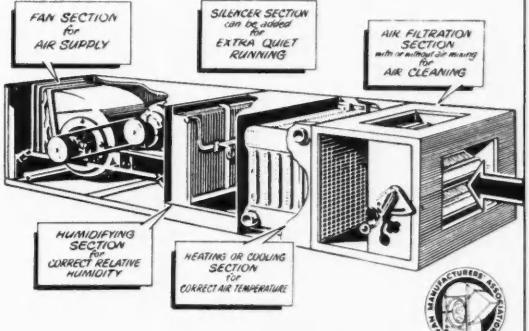
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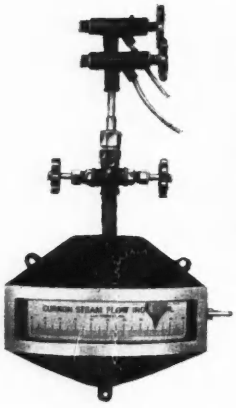

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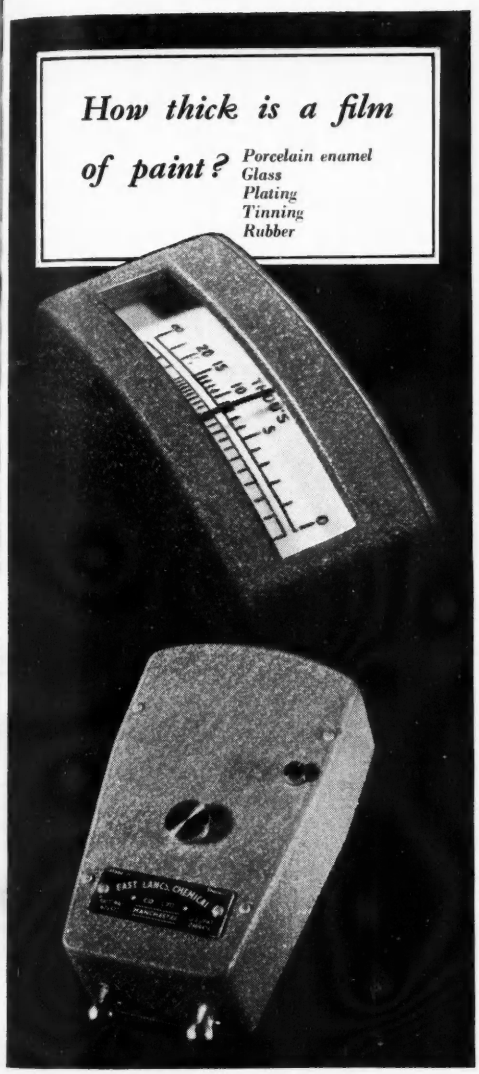

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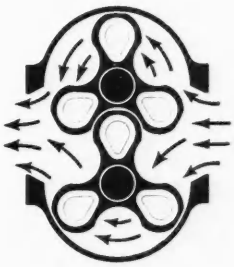

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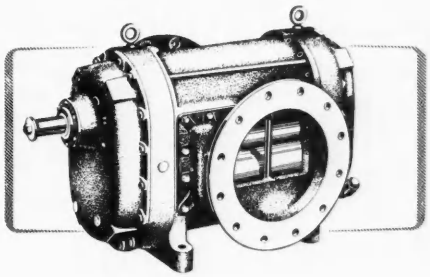

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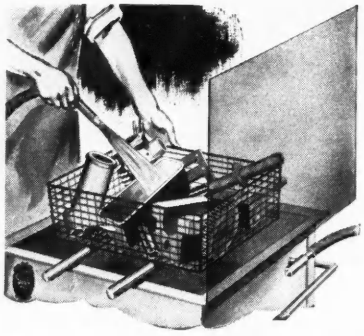

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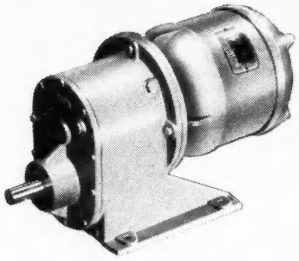

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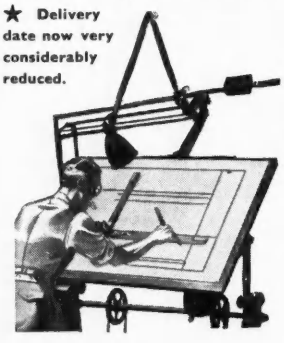

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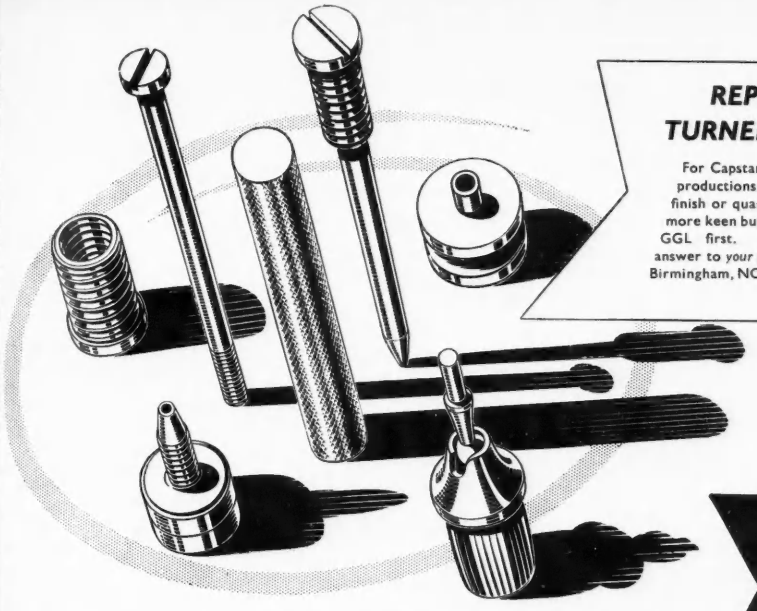

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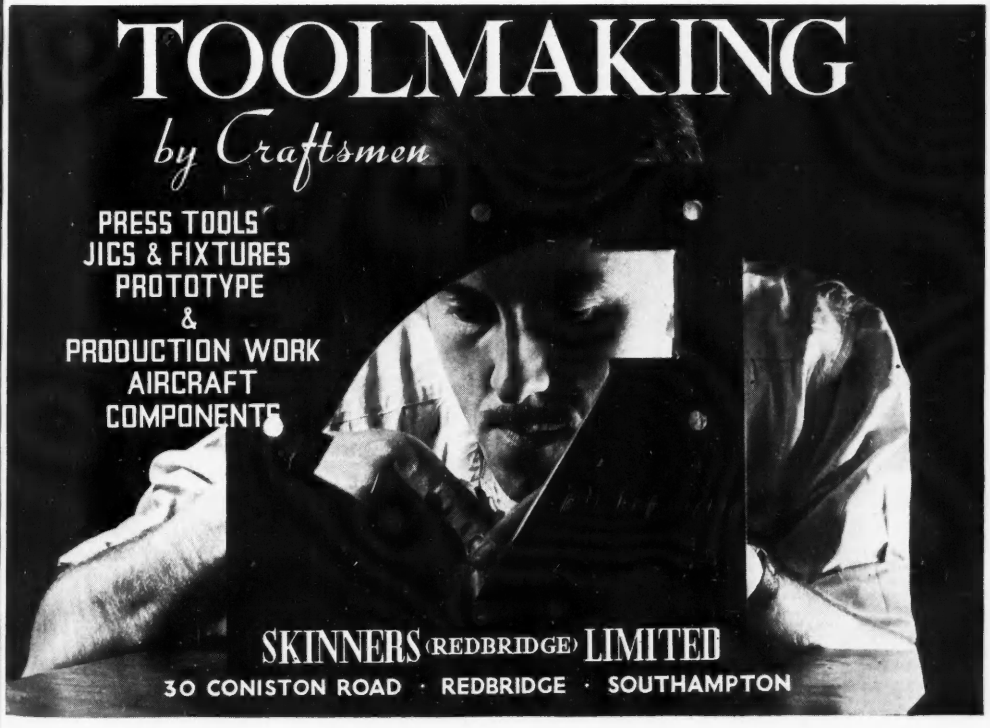

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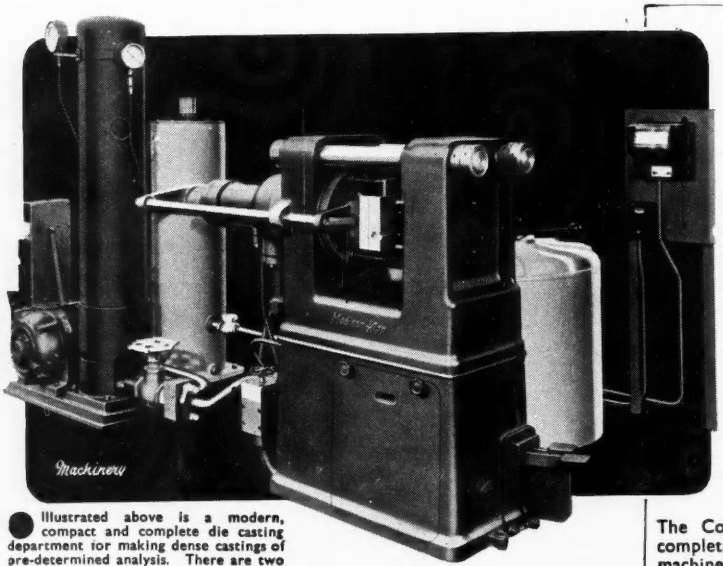

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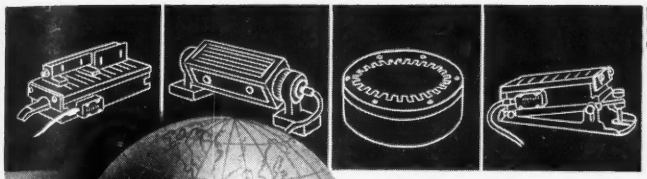

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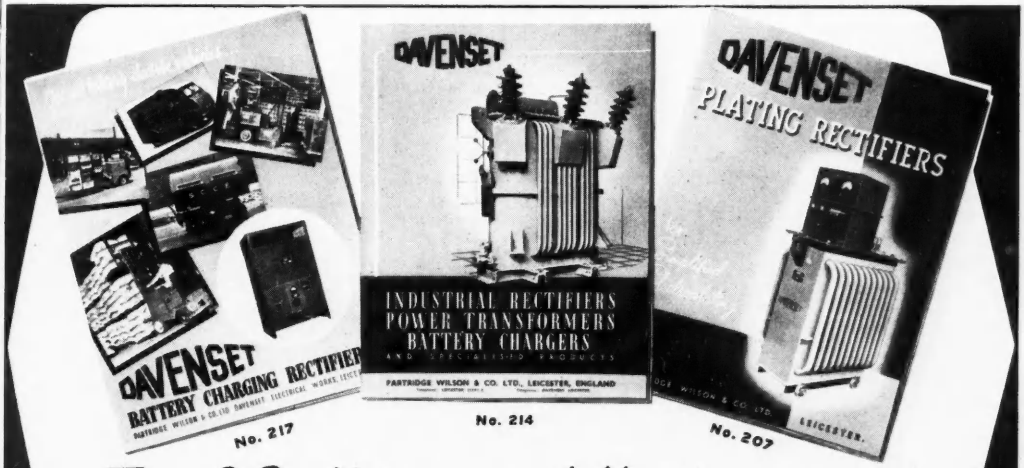

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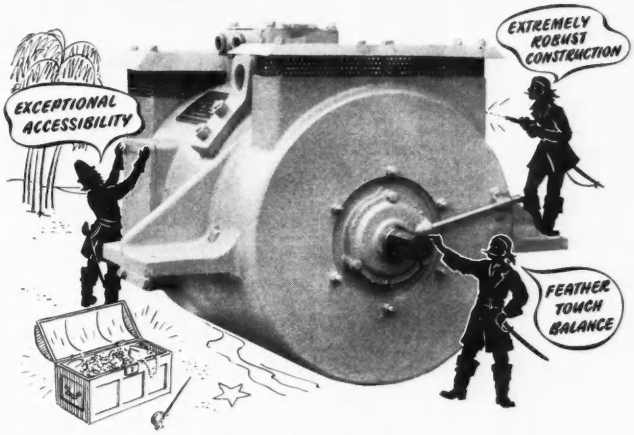

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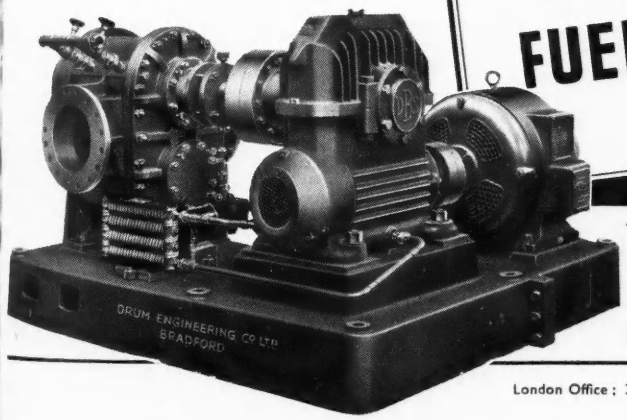

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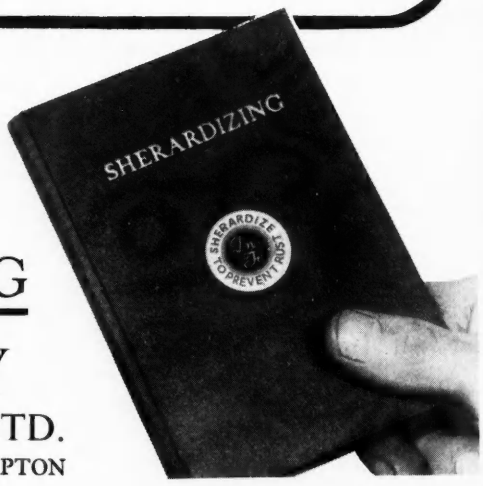

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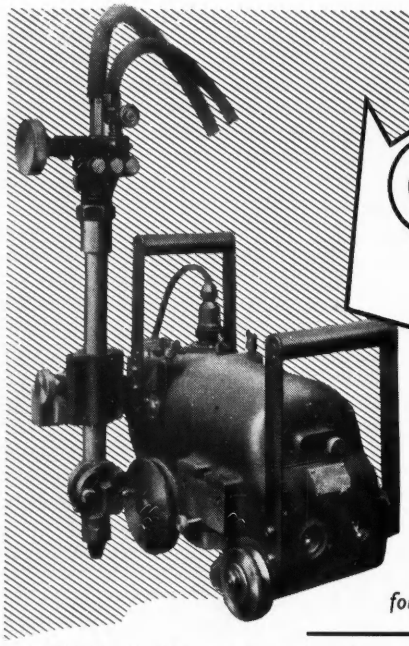

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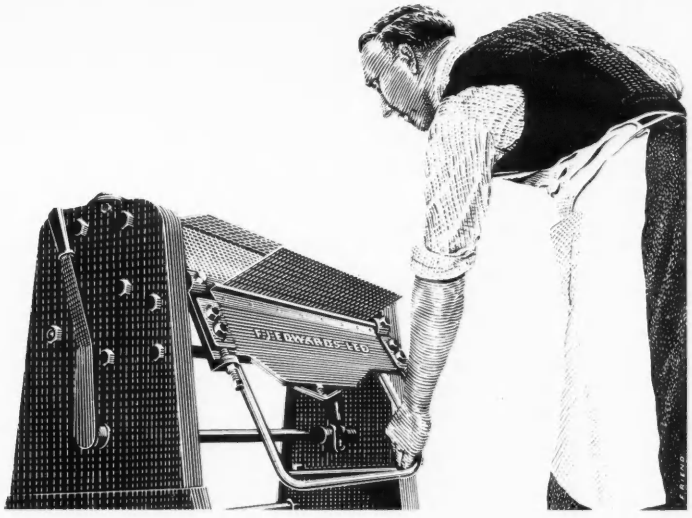

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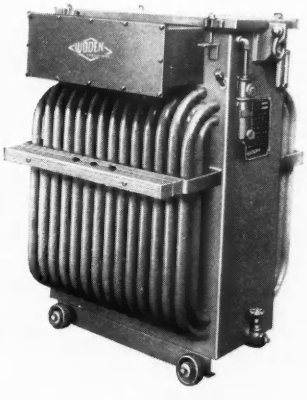

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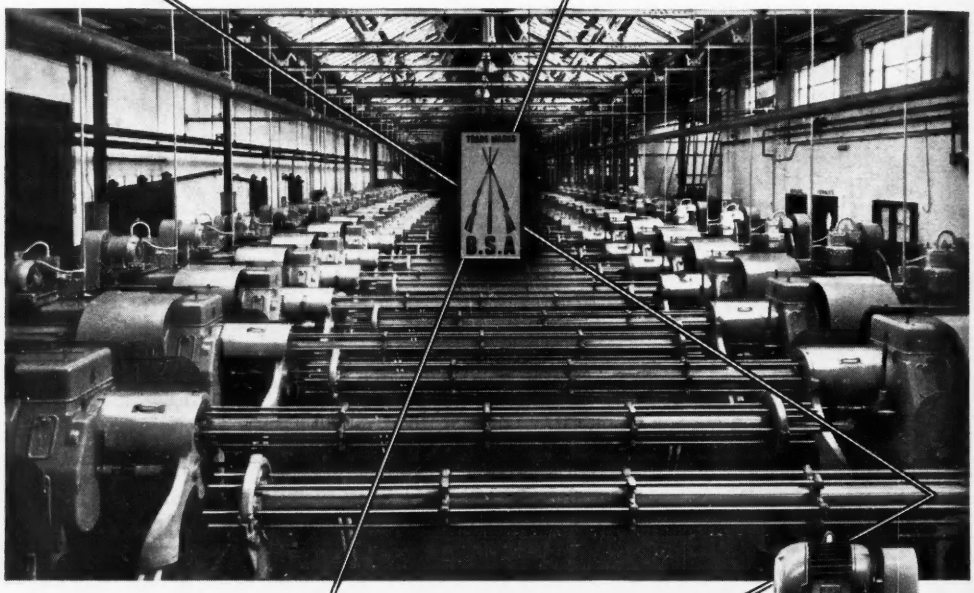

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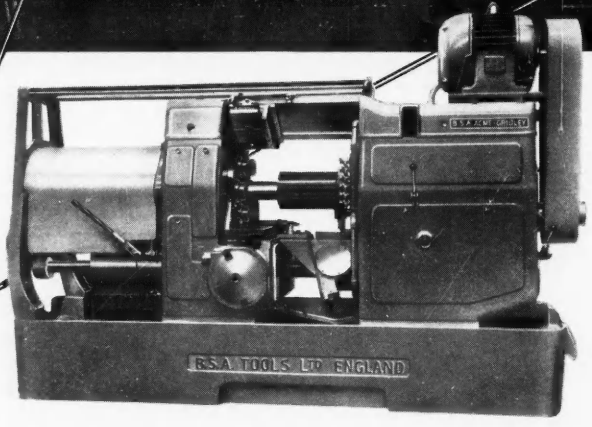

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